THE SCIENCE MANUAL SERIES.

PART I.

CHEMISTRY.

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PREFACE TO THE FIRST EDITION.

AT the sight of a new publication, one is inclined to exclaim "There is no end of making books; is there anything whereof it may be said, this is new?" But one ought to see, that though the Science Primers are interesting and valuable, the University papers that are set year after year require that the knowledge to answer them is not new but is of varied and varying applications.

The following pages were originally prepared for my class and were not meant to be placed in the hands of students in general. The simple language in which the notes are written, the arrangement that is hoped to be helpful to master the Primer, the concise and at the same time the full treatment that the subject has received, the numerous exercises which include all the University questions arranged under the different chapters,—that these will help the candidates preparing for the Matriculation examination, is the only apology for sending the notes to the press.

TINNEVELLY,
April 1898.

J. A.

PREFACE TO THE FOURTH EDITION.

In the present edition, a few diagrams are added and some of the sections are re-arranged and re-written with a view to make the book suitable to the Fourth Form also. Chapters I—IV, VI—VIII may be taught with advantage in this Form. The last six papers set for the Matriculation examination are given together separately to give an idea to the candidates preparing for that examination as to the kind of knowledge that is required of them.

Any corrections or suggestions for improvement will be thankfully received.

PALAMCOTTAH,
December 24th, 1901.

J. A.

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CHEMISTRY.

CHAPTER I.

Elements.

1. **Definition of Chemistry.**—We know that a large number of changes is taking place around us. These changes are said to be either physical or chemical, and form the subject-matter of Physics and Chemistry.

If a piece of iron is heated till it becomes red-hot, it is still iron. Hot iron has the same composition and weight as cold iron. The change that the iron has undergone has not altered its composition or its weight but only its state as regards heat. Cold iron becoming hot is an example of physical change. Hence a **Physical change** *is a change in the state of a body but not in its composition.* In the same way, when a body moves, when a bell is giving a sound, when water becomes steam, when ice melts, or when a lump of sugar dissolves in water, we have examples of physical change. *The science which treats of the changes that take place in the state of bodies and of the forces which produce them* is known as **Physics.**

If iron is exposed to moist air, it takes up something from the air and becomes covered with a reddish brown substance called *rust.* Rust is not iron, but a new substance of a different composition as well as of a different colour, weight and hardness. The formation of rust is an example of chemical change. Hence a **Chemical change** *is a change in the composition of substances, resulting in the formation of new substances having new properties.* In the same way, when fresh milk becomes sour, when gun-powder is ignited, when lime-stone is heated, or when a

candle burns, we have examples of chemical change. *The science which treats of the changes that take place in the composition of bodies and of the consequent changes in their properties* is known as **Chemistry.**

2. **Elements and Compounds.**—The various substances in this world are made up of one substance or more than one.

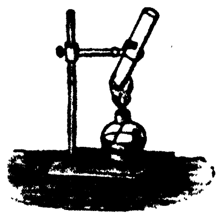


Fig. 1.

Experiment 1.—Heat some red powder called mercuric oxide in a hard glass tube. It becomes dark, and after some time a colourless gas escapes; while a bright shining film is deposited on the upper and cooler parts of the glass inside. If this film is scraped, the particles will run together and form globules of mercury. The colourless gas is oxygen. For a *red-hot* splinter of wood at once bursts into flame, when introduced into the gas.

We conclude therefore that the red powder is made up of two substances, mercury and oxygen. This powder from which two different kinds of matter have been obtained is called a *Compound*. Now, chemists have not been able by any process yet known to get out of mercury and oxygen any substance different from them. Mercury and oxygen are therefore called *Elements*.

Expt. 2.—Heat some yellow sulphur and red copper turnings together in a flask. The sulphur melts and combines with the copper, forming a black substance called copper sulphide.

We know therefore that the black substance is made up of two substances, copper and sulphur. This substance resulting from the union of two different kinds of matter is also called a *Compound*. But chemists have never succeeded in producing sulphur or copper by the combination of other substances. Hence sulphur and copper also are called

An element *is*, therefore, *a substance out of which nothing different from itself can be got*; in other words, *it is a substance which cannot be split up into two or more different kinds of matter.*

A compound *is a substance out of which two or more different kinds of matter can be got, or which results from the union of two or more different kinds of matter.*

There are over 72 elements known at present; new ones are being discovered from time to time. All other substances are either compounds, or mixtures of elements and compounds. For the sake of convenience, the elements are divided into *metals* and *non-metals*. The following table gives the names of the most important non-metals and metals with their symbols and atomic weights:

Non-Metals.

Names.		Symbols.		Atomic weights.
Hydrogen	...	H.	...	1
Oxygen	...	O.	...	16
Nitrogen	...	N.	...	14
Chlorine	...	Cl.	...	35·5
Fluorine	...	F.	...	19
Bromine	...	Br.	...	78
Carbon	...	C.	...	12
Sulphur	...	S.	...	32
Phosphorus	...	P.	...	31
Silicon	...	Si.	...	28

Metals.

Iron (Ferrum)	...	Fe.	...	56
Aluminium	...	Al.	...	27
Calcium	...	Ca.	...	40
Magnesium	...	Mg.	...	24
Sodium (Natrium)	...	Na.	...	23
Potassium (Kalium).		K.	...	39
Copper (Cuprum)	...	Cu.	...	63

Names.		Symbols.		Atomic weights.
Zinc	...	Zn.	...	65
Tin (Stannum)	...	Sn.	...	118
Lead (Plumbum)	...	Pb.	...	207
Mercury (Hydrargyrum)		Hg.	...	200
Silver (Argentum)	...	Ag.	...	108
Gold (Aurum)	...	Au.	...	197
Platinum	...	Pt.	..	195
Barium	...	Ba.	...	137
Manganese	...	Mn.	...	55
Chromium	...	Cr.	...	52
Antimony (stibium)	...	Sb.	..	120

3. **Solution.**—Some solid substances, when placed in a liquid, become liquid themselves. Their particles get so minutely divided and so thoroughly diffused into the pores of the liquid that they are altogether invisible even under the microscope; there is no part of the liquid in which the substance is not present. The solid is said to *dissolve* and the liquid is then called a *Solution.*

Expt. 3.—Put some sugar in water and stir the liquid well. The sugar disappears and every drop is found to have the taste of sugar. The sugar is then said to be in a state of solution.

4. **There is no loss of weight by solution.**

Expt. 4.—Take one pound of water and one ounce of common salt. Mix the two substances in a glass vessel and stir till the whole of the salt is dissolved. Now weigh the mixture. It will be found that there is no loss in weight, the solution weighing 1 lb. 1 oz.

5. **Conditions favourable for the solution of solids.**

(1) *Increase of temperature.*—A liquid at a higher temperature can dissolve more of a solid than the same liquid at a lower temperature.

Expt. 5.—Dissolve common salt in some cold water, stirring and adding salt till some quantity of it remains undis-

solved. If the water be now heated, the undissolved portion will begin to dissolve, and may completely dissolve if the heating is continued.

(2) *The divided state of the solid.*—A liquid dissolves a solid more readily when it is in a state of powder than when it is in the form of large pieces.

Expt. 6.—Take a pound of alum in large pieces and another pound in fine powder and place them in two vessels containing equal quantities of water at the same temperature. It will be found that the powder dissolves more *rapidly*, though the total *quantity* that is ultimately dissolved will be the same in both cases.

6. **Saturation.**—When a given quantity of a liquid has dissolved as much of a substance as it can at a given temperature, the solution is said to be *Saturated*.

Expt. 7.—Take some alum in fine powder and add little by little to cold water, stirring the liquid well. The alum will dissolve in the water. Continue this till it ceases to disappear, and when this is the case, the mixture is termed *a saturated solution* of alum in water.

7. **To obtain a solid from its solution.**

Expt. 8.—Pour into a China-dish a little of the solution of nitre in water, and apply heat. After a time, the whole of the water will be driven off in the form of vapour, and a small quantity of nitre will be left in the dish.

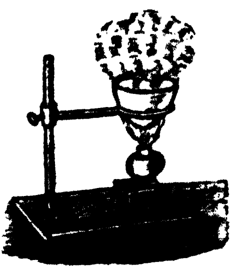


Fig. 2.

8. **The solubility of different solids varies.**—Some solids do not at all dissolve in water; as, sand, chalk; some dissolve very slightly, as quick-lime, gypsum; others dissolve in considerable quantities, as nitre, common salt, sugar. Again, a solid which does not dissolve in one liquid may dissolve in another. Thus, phosphorus

and sulphur dissolve readily in carbon-disulphide, camphor in alcohol and sand in hydrofluoric acid, though not one of these dissolves in water.

9. To find whether a solid dissolves in a liquid.

Expt. 9.—Take a small quantity of the substance in the state of fine powder. Put it into a test-tube containing the liquid. Stir it well. If it disappears altogether, the substance has dissolved in it. If not, apply heat. Should there be any powder still, filter the liquid and then evaporate the clear filtrate in a dish. If the solid has dissolved in the liquid, a residue will be left.

10. **Uses of solution.**—(1) *Solution aids chemical change.*

Expt. 10.—If we mix some dry sulphate of iron with a little dry potassium ferro-cyanide, no change will be noticed. But if we make a solution of each substance separately and mix the solutions together, chemical action ensues, and a new substance of a peculiar blue colour is formed.

(2) *The insoluble ingredients of a mixture can be separated from the soluble ones.* Suppose we have a mixture of sand and sugar. The insoluble sand can be separated by stirring the mixture with water and after some time pouring off the solution.

11. ***Solution of Gases.***—Like solids, gases differ from one another in solubility. Some gases dissolve freely in water, as hydrochloric acid and ammonia, others only sparingly, as carbonic acid gas and common air. The solution of ammonia in water is sold under the name of *Liquor Ammonia*, and that of Hydrochloric acid is sold as *Muriatic acid*. *Soda-water* is simply water containing carbonic acid gas in solution. Common air dissolves in water, giving to it its pleasant and fresh taste and serving for the breathing of fishes.

A gas dissolves more readily in a liquid when it is cold than when warm. So gases held in solution by cold

water may always be driven off by heat. Thus, if you warm some water in a flask, you can see bubbles of gas escape. If liquor ammonia be boiled, the whole of the gas is driven off. Again, increase of pressure helps the solution of a gas. When the pressure is lessened, the dissolved gases fly off. Thus, when a bottle of Soda-water is opened, the gas bubbles out rapidly, giving to the liquid a boiling appearance.

12. **Solution of liquids in liquids.**—Some liquids are soluble and some are insoluble in one another. For instance, Methylated spirit and sulphuric acid are soluble in water, while oil and mercury do not at all dissolve in it.

13. **Precipitation.**—When one clear solution is added to another clear solution, an insoluble compound sometimes forms and separates from the liquid, shewing minute particles in suspension, or giving the liquid a cloudy appearance, or forming clots at the bottom. This insoluble substance is called a *precipitate* and the process, *precipitation.*

Expt. 11.—Make a solution of common salt in water and add to it a solution of silver nitrate; a white precipitate is formed due to the formation of an insoluble substance named silver chloride.

14. **Impurities in a liquid.**—There are two kinds of impurities which a liquid may contain:—impurities in suspension or suspended impurities, and impurities in solution or dissolved impurities. When a liquid holds particles which it cannot dissolve, it is said to contain **suspended impurities**, for example muddy water. When a liquid holds substances in solution, it is said to have **dissolved impurities**, for example, sea-water.

15. **Separation of impurities.**—(1) Suspended impurities are removed by filtration.

Filtration is the process of purifying a liquid from *suspended impurities* by passing it through some porous substance—such as charcoal, sponge, or blotting paper—which allows only the liquid to pass through but not the suspended solid particles. (Fig. 3.) The apparatus employed in filtration is called a filter.

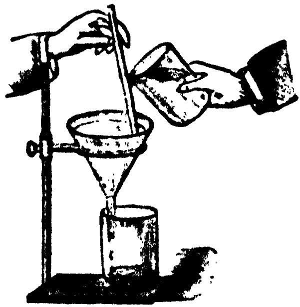


Fig. 3.

More commonly, the suspended impurities are removed by *decantation*, that is, by allowing the liquid to stand and thus enabling the particles to settle down and then pouring off the clear liquid.

(2) Dissolved impurities are removed by distillation.

Distillation is the process of purifying a liquid from *dissolved impurities* by boiling it and collecting and

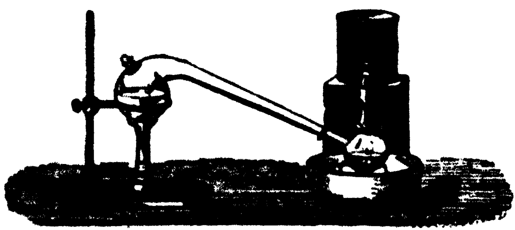


Fig. 4.

condensing the vapour. (Fig. 4.) This process is much used on board ships for getting drinkable water from sea-

water. *Distilled water* is pure water without any impurity whatever.

The vessel in which the liquid is boiled is called a *retort*, and consists of a flask-shaped vessel to which a long neck is attached.

16. Dissolved impurities cannot be removed by filtration.

Expt. **12.—Add a few** drops of **indigo solution to water, and filter this through a** paper filter. **The colour will not** be **got rid of, since the indigo** is dissolved **in the water.**

17. Crystallization is the process by which a substance separates from its solution in the form of solids having regular geometrical shapes.

A crystal is a solid of some geometrical shape, that is formed when a saturated solution of a substance is cooled or evaporated.

Methods of making crystals.—(*a*) *Cooling a hot saturated solution.*

Expt. 13.—Make a strong solution of alum in hot water and allow it to cool undisturbed A portion of the alum will separate out in the form of crystals.

If the solution is cooled rapidly and with agitation, the crystals will be very small; if slowly and without disturbance, they will be large and well-defined.

(*b*) *Evaporating a solution.*—Common salt is manufactured from sea-water by evaporation.

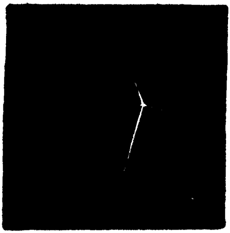
Expt. 14.—Dissolve some nitre in water and expose the solution to the air in a China-dish. The liquid will evaporate and white crystals of nitre will be formed.

(*c*) *Fusion.*—In some cases, crystals are obtained by melting the substance and allowing it to solidify, for example, sulphur, bismuth and lead.

Expt. **15.—Melt some sulphur in a clay crucible, and allow it to cool until a crust forms at the surface. Make a hole**

through the crust and pour out the liquid portion. Needle-shaped crystals of sulphur will be found beneath the crust.

Uses.—(1) Different substances have different crystalline forms. Thus, common salt and fluor-spar crys-



Form of a Crystal of Alum

Form of a
Fig. 5. Crystal of Copper Sulphate.

tallize in cubes, nitre and zinc sulphate in prisms, washing-soda, alum in octahedral and calc-spar in hexagonal forms. This difference in form helps us to distinguish substances from one another. (Fig. 5.)

(2) The process can be used to separate the ingredients of certain mixtures. Thus, if we have alum and blue stone mixed, we can separate them by dissolving the mixture in hot water and allowing the solution to cool; when, white crystals of alum and blue crystals of blue stone appear separate.

Note 1.—Many salts, when they crystallize out of their solution, combine with a fixed quantity of water which is necessary to keep up the form they assume. This water is called *water of crystallisation*.

Note 2.—Certain substances when exposed to the air, part with their water of crystallisation and crumble down to powder, losing their crystalline form, colour, &c. These are called *Efflorescent salts*, *e.g.*, Green vitriol.

Note 3.—Some substances readily absorb moisture from air and become liquids. They are called *deliquescent salts*, *e.g.*, Potassium carbonate, calcium chloride.

18. Difference between a chemical compound and a mechanical mixture.

(i) *In a chemical compound, the constituents exist in fixed proportions by weight; but in a mixture, they may be in any proportion.* For example, if we analyse any quantity of water, we always find that for every one part by weight of hydrogen, there are eight parts by weight of oxygen. But a mixture of sugar, coffee, and milk may be made in any proportion we please.

(ii) *The properties of a chemical compound are entirely different from those of the combining substances; whereas, a mixture partakes of the properties of its constituents.* Thus, copper turnings are red, sulphur is yellow; while the compound of sulphur and copper is black. A solution of sugar tastes sweet and that of common salt bitter; whereas, a mixture of the two is both sweet and bitter.

(iii) *When a chemical compound is produced, heat is evolved during the process, but when a mechanical mixture is made, no heat is given off.*

Expt. 16.—Pour some cold water on a lump of quicklime. Both the lime and the water get hot, and a fine, dry, white powder called slaked lime is formed.

Fig. 6.

Expt. 17.—Heat some flour of sulphur and copper turnings in a flask, till the sulphur melts and touches the copper. Then remove the source of heat. The sulphur unites with the portion of copper in contact with it producing much heat. This heat causes the copper not in contact to glow with a lurid red light and to melt down into the

sulphur, and a black substance called copper sulphide is left in the flask.

Note.—In the case of combination between gases, there is generally a contraction of volume. The resulting compound occupies a less volume than the constituents together. For example, when two volumes of hydrogen and one of oxygen are made to unite together by an electric spark, only two volumes of steam are formed.

(iv) *The constituents of a mixture are in almost all cases separable by simple mechanical means such as sifting, solution, filtration and crystallization. On the other hand, in a chemical compound the substances cannot be separated by any simple ordinary means.* For instance, if we have a mixture of sulphur and iron filings, the iron may be separated by passing a magnet over the mixture, but in a chemical compound this is not possible.

Gunpowder, air and sea-water furnish good examples of mixtures. Take, for instance, gunpowder which is made up of charcoal, sulphur and nitre. We call it a mechanical mixture for the following reasons:—

(*a*) The constituents are not mixed in fixed proportions by weight: for, the various kinds of powder are made in different proportions by weight. Thus, English gunpowder contains 75 parts of nitre, 15 of charcoal and 10 of sulphur; while French gunpowder, 75 of nitre, 12·5 of charcoal and 12·5 of sulphur.

(*b*) Its properties are not quite different from those of its constituents; thus, it has the colour of charcoal, the smell of sulphur and the taste of nitre.

(*c*) No heat is produced when the constituents are mixed together.

(*d*) The constituents can be easily separated by mechanical means.

This may be done by shaking up a little gunpowder with water and filtering. The charcoal and sulphur, being insoluble in water, are left behind in the filter-paper, whilst the nitre, having dissolved in the water, runs through, and can be obtained from its solution by evaporation. Since sulphur is soluble in carbon disulphide, whilst charcoal is not, pour on to the remaining mixture a little of this liquid, and catch it in a test-tube as it runs through. Let the

same liquid pass through the mixture two or three times, and then allow it to evaporate slowly away by pouring it into a large watch-glass and letting it stand, when crystals of sulphur are left behind. The charcoal still remains on the filter-paper.

Questions.

1. When is a substance said to undergo a physical change, and when a chemical change? What kind of change is (*a*) turning water into steam, (*b*) the rusting of iron?

2. A stone falling upon some gunpowder causes it to explode. Which is the physical and which is the chemical change? Give reasons.

3. Explain the difference between elements and compounds with the help of experiments.

4. How will you test the presence of oxygen?

5. Classify the following substances into (*a*) elements, compounds, or mixtures; (*b*) solids, liquids and gases:—chalk, mercury, water, air, silicon, lead, gold, ink, common salt, sea-water, nitre, sodium, charcoal, phosphorus, gunpowder, and chlorine.

6. How does filtration differ from distillation, and a crystal from a precipitate?

7. Describe the methods of obtaining crystals and show how you would prepare crystals of sulphur, alum and common salt.

* 8. Explain how drinkable water can be obtained from sea-water. What takes place when a solution of silver nitrate is added to a solution of common salt?

9. Explain how you would separate the constituents of the following mixtures:—Muddy water, sea-water, a mixture of alum and blue stone.

* 10. You are given a powder consisting of charcoal and saltpetre. How would you separate the two substances from the mixture and obtain both in the pure state?

* 11. Distinguish between a mechanical mixture and a chemical compound.

12. Describe experiments to prove that heat is felt when chemical union takes place.

13. Given finely powdered sulphur and finely divided copper, show the difference between chemical combination and mechanical mixture.

* 14. Gunpowder is made by mixing sulphur, charcoal and saltpetre. Is it a chemical compound of those substances, and if not a chemical compound, what is it? Give the reasons for your answer.

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* University questions are marked with an asterisk.

15. State what takes place when (1) red oxide of mercury is heated, (2) water is poured on quick-lime, (3) a red-hot splinter of wood is introduced into oxygen, (4) sulphur and copper turnings are heated together.

CHAPTER II.

FIRE.†

19. **The burning of a candle.**—When a candle burns, the carbon and the hydrogen of the wax unite chemically with the oxygen of the air and produce carbonic acid gas and water; while some of the carbon escapes unburnt as smoke or soot.

Note.—All fats and oils are composed of carbon and hydrogen and are called hydro-carbons.

20. **Carbonic acid gas is formed when a candle burns.**

Expt. 18.—If some clear lime-water be poured into a bottle in which a candle has not been burnt and be shaken, it remains clear. If poured into a bottle in which a candle has been burnt, the lime-water becomes milky. This milkiness is due to the presence of chalk which is made up of lime and carbonic acid gas.

Lime-water is prepared by letting some fresh lime stand in water, shaking it up and then drawing off the liquid after it gets quite clear again.

Note.—Carbonic acid gas (carbon dioxide) is a compound of carbon and oxygen. Chalk (calcium carbonate) is a compound of calcium, carbon and oxygen. Quick-lime (calcium oxide) is a compound of calcium and oxygen. Water or steam (hydrogen) is a compound of hydrogen and

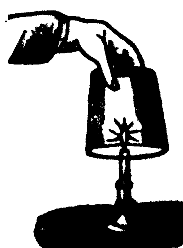

Fig. 7.

21. **Water is formed when a candle burns.**

† Fire is the heat given off when bodies burn or combine chemically.

Expt. 19.—If we hold a cold, dry, bright, glass tumbler over the flame of a candle, the bright glass is at once dimmed, and little drops of water are formed on the inside of the glass. (*Fig.* 7.)

When a candle burns, water is given off as steam which is invisible. Steam condenses into water, when it comes in contact with any cold surface.

22. **Carbon is contained in the wax of a candle.**

Expt. 20. Press a sheet of white paper on to the flame of a candle so as not to burn it. The sheet becomes stained with a black ring of soot or carbon.

Expt. 21.—Take a test-tube with a little water, and hold it in the flame of a candle for some time. It becomes covered with black carbon at the bottom.

23. **Nothing is lost when a candle burns.**

Expt. 22.—Take a glass tube with a very narrow part in the middle, and the lower end closed with a cork in which some holes are bored. Into one of these holes, stick a piece of taper and place in the upper part of the tube some pieces of caustic soda. Weigh the tube with its contents. Then take out the cork, light the taper and quickly replace it. The outside air, passing through the holes in the cork, will keep the candle burning. After the taper has burnt for a few minutes, blow it out and weigh the tube again. It will be seen that the tube and its contents are now heavier, although part of the candle has burnt away.

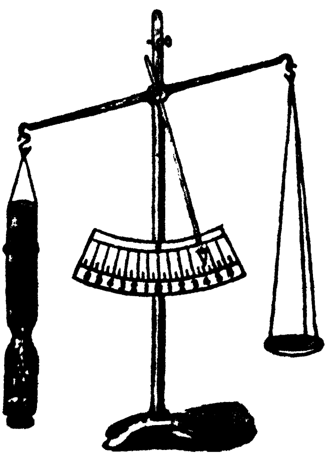
Fig. 8.

When the taper burnt, it gave off steam and car-

bonic acid gas. These were absorbed by the caustic soda. Now, the steam and the carbonic acid gas are only portions of the candle combined with the oxygen of the air. Since oxygen has weight, the combination of oxygen with the substances of the candle has increased the weight. If we could weigh the outside air both before and after experiment, it would be found to have lost exactly as much weight as the burnt taper gained, *viz.*, the weight of the oxygen that has combined with it.

Thus we learn that, though a candle disappears when it is burnt, the materials of which it is made are not really destroyed or lost, but they undergo chemical change, whereby the visible, solid wax and wick become invisible, gaseous carbonic acid and steam.

Note.—Caustic soda (sodium hydroxide) is a compound of sodium, hydrogen and oxygen.

24. **Burning** or **Combustion.**—*Burning or combustion is the chemical union of two substances attended with great heat and light.* When the amount of light and heat is feeble, the combustion is described as *slow;* on the other hand, when they are considerable, the combustion is said to be *rapid.*

In ordinary language, the name combustion is given to the rapid oxidation of substances accompanied with great heat and light. Thus, when we say that a house or a hayrick is burning, it is meant that the materials of the house or the constituents of the hay are merely combining with the oxygen of the air, forming new compounds and producing heat and light by the chemical union.

Some examples of combustion in which oxygen does not take part: (1) when melting sulphur and heated copper are brought together, the two unite chemically producing a lurid red light; (2) when a piece of phosphorus is brought in contact with some iodine, the two combine together producing heat and light; (3) when powdered antimony is thrown into a bottle of chlorine gas, sparks of fire are seen.

Note.—Oxidation is the act of combination of any substance with oxygen.

25. Combustible and supporter of combustion.—In all processes of combustion, it is customary to speak one of the substances taking part in the chemical change as the *combustible* substance and the other as the *supporter of combustion*. Usually, that substance which surrounds the other is called the supporter of combustion. Thus, when a candle burns in air, the air is spoken off as the supporter of combustion, while the candle is termed the combustible.

A gas is said to be *combustible* when it is capable of itself burning, and is said to be a *supporter of combustion* when it does not itself burn, but allows other bodies to burn in it. Thus, hydrogen and carbon mon-oxide are said to be combustible gases because they can burn in air. Oxygen and chlorine are spoken of as supporters of combustion, because they allow a candle and other substances to burn in them.

It should, however, be borne in mind that the two terms combustible and supporter of combustion are only *relative* and do not imply any difference of function; for instance, hydrogen and oxygen may be either, according to circumstances.

Combustion being chemical combination attended with great heat and light, it can only be brought about in the case of hydrogen and oxygen by making hydrogen combine with oxygen or oxygen with hydrogen. Thus, when a burning taper is pushed into a bottle of hydrogen gas held mouth downwards, the hydrogen burns at the mouth; because there it combines with the oxygen of the air. On the other hand, the taper does not burn inside, because there is no oxygen for chemical union. If now a jet of oxygen be introduced through the mouth of

burning hydrogen, it burns in the bottle of hydrogen chemically combining with it.

Similarly, a jet of hydrogen, introduced into chlorine gas and lighted, burns forming white fumes of hydrochloric acid. Here, hydrogen is the combustible gas and chlorine, supporter of combustion. Again, chlorine burns in an atmosphere of hydrogen, thus becoming a combustible gas.

26. **Conditions of Combustion.**—(i) *Rise of temperature.*—To cause a substance to burn, it must be raised to a certain degree of temperature at some portion at least of its mass. But when once started, combustion generally continues by itself, owing to the heat produced by the chemical action. For example:

1. A candle does not burn until we light it. For, the constituents of the candle do not combine with the oxygen of the air, until we start the chemical union by applying heat.

2. When a piece of phosphorus is exposed to the air, it fumes in the air, undergoing slow combustion. As the action proceeds, heat is developed and the phosphorus melts and bursts into flame, emitting dense, white, strongly smelling fumes of phosphoric oxide.

(ii) *Free supply of oxygen.*—This is necessary to continue combustion. Bellows are used simply to increase the supply of air. Conversely, to diminish or to prevent combustion, it is sufficient to diminish the supply of air or to stop it completely. The flame of a spirit lamp is put out by covering the top.

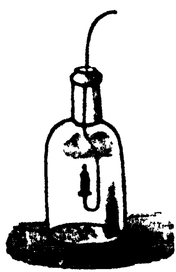

Fig. 9.

Expt. 23.—Burn a candle in a bottle with a narrow neck. It burns brightly at first. After a short time, it flickers feebly and finally goes out. This is due to the consumption of the oxygen gas originally contained in the bottle.

If a substance has once been completely burnt, it can no longer burn. Thus, carbonic acid gas and steam, the products of combustion of carbon and hydrogen with oxygen, do not at all burn in air.

Questions.

* 1. How can you prove that water and carbonic acid gas are formed when a candle burns?

* 2. Describe an experiment to illustrate the fact that when chemical change occurs, there is neither gain nor loss of weight, but that the bodies resulting from the action have exactly the same weight as the bodies which took part in it.

* 3. What is meant by oxidation? Give some familiar examples.

4. What is noticed when a candle is burnt in a vessel (*a*) with a narrow neck, (*b*) with a wide mouth? Give reasons for your answer.

5. Explain why (*a*) a candle continues to burn, after it is lighted, and (*b*) a piece of phosphorus takes fire by mere exposure to air.

* 6 Explain the statement that oxidation occurs when a candle burns. How would you show this to be the case?

7. Describe any experiments to show that (*a*) heat is given off when chemical union takes place, (*b*) carbon is contained in the wax of a candle.

8. What is combustion? Give some examples.

9. Name the elements of which the following are composed and give their chemical names: oil, chalk, caustic soda, water, lime, soot, copper sulphide, steam and carbonic acid gas.

* 10. Explain the terms "combustible" and "supporter of combustion" as applied to gases. How may hydrogen and chlorine be either according to circumstances?

CHAPTER III.

AIR.

27. **What is air?** Air is a mixture of gases, consisting chiefly of oxygen and nitrogen. The average proportions of oxygen and nitrogen may be given as,

	By volume	By weight
Oxygen	21	23
Nitrogen	79†	77
	100	100

† 1 per cent. of Argon present is here included with the nitrogen.

Besides oxygen and nitrogen, air contains variable quantities of carbonic acid gas, water-vapour, ammonia, nitric acid and ozone. Besides the gases, there is always present in the air a quantity of suspended matter, the chief of which is dust-particles.

Ammonia is a compound of hydrogen and nitrogen. Nitric acid (Hydrogen nitrate) is a compound of hydrogen, nitrogen and oxygen. Ozone is a condensed form of oxygen.

28. **Air is a mixture and not a chemical compound.**—*Reasons.*—(i) Substances known to be chemical compounds do not vary in composition; but the composition of air does vary slightly in different places.

(ii) The properties of air are intermediate between those of its constituents. If it were a chemical compound, it would have quite different properties from them.

Thus, a candle which burns in air moderately is put out in nitrogen, but burns very brilliantly and energetically in pure oxygen. Again, oxygen has a sp. gr. of 1·1 and nitrogen a sp. gr. of 0·97, while air has a sp. gr. of 1.

(iii) When nitrogen and oxygen are mixed together in the proportion in which they occur in air, there is no sign of chemical union, such as evolution of heat or contraction of volume; and yet the mixture acts just like common air.

(iv) The oxygen and nitrogen in the air may be separated to a certain extent by simple mechanical means such as diffusion through a porous substance, or dissolving in water.

(v) The proportion by weight in which oxygen and nitrogen are present in air bears no simple relation to the combining weights of these elements.

29. **Compositon of air by volume.**

Expt. 24.—Take some water in a basin and float on it a small China-dish. Place a small piece of phosphorus in the dish and invert over it a stoppered bell-jar, keeping the jar well under water. Remove the stopper, and ignite the phosphorus by touching it with a hot wire. Replace the stopper immediately. At first, the water in the jar is driven down by the expansion of the air caused by the heat of the flame, and the jar is full of dense white fumes of phosphoric anhydride. After a while, the phosphorus ceases to burn, and the jar becomes cool. The fumes now gradually dissolve in the water forming phosphoric acid, and the water rises in the jar to a fifth of the space previously occupied by air.

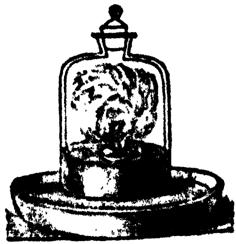

Fig. 10.

Pour water into the basin till the level of the water outside the jar is equal to that inside. Now remove the stopper, and introduce a burning taper into the jar. At once it goes out. Transfer the gas to another vessel and shake it with lime-water. The gas does not turn the lime-water milky.

From this we learn that air is composed of two gases :—One which will support combustion and forms about one-fifth of the air and the other which will not support combustion and forms about four-fifths of the air. The former is called **Oxygen** and the latter **Nitrogen**.

Note.—Phosphorus is kept under water because it readily takes fire in air. Phosphoric acid is a compound of phosphorus, oxygen and hydrogen. An acid has the property of turning blue litmus red. So the water over which phosphorus has been burnt [illegible] this property.

30. **Carbonic acid gas in air.**—*Its sources.*—Carbonic acid gas is given off when (1) animals breathe, (2) carbon-compounds burn, (3) vegetable and animal matter ferments or decays, (4) lime-stone is heated. It is also evolved from coal-mines and volcanoes.

Though carbonic acid gas is derived from so many sources, its proportion in air on the whole does not increase, but is fairly constant, being about *4 parts in 10,000*. This constancy is maintained by (1) the action of plants which in the presence of sunlight decompose it, taking carbon for their growth and setting free oxygen, (2) the action of rain which dissolves and carries down a portion of it, as it falls, and (3) the diffusion by wind. Its presence in air is proved by the following experiment:

Expt. 25.—Pour some lime-water into a shallow vessel and expose it to the air for some time. A white thin film of chalk is formed on the surface.

31. **Presence of water-vapour in air.**—When an open vessel of water is exposed to the air, the water gradually disappears. It has passed off in the form of invisible vapour, which mixes with the air. The water-vapour in the atmosphere is derived from oceans, rivers, lakes, &c., in a similar manner by evaporation.

Expt. 26.—Place a few pieces of dry calcium chloride or caustic soda on the table. The pieces gradually become liquid. This is owing to their absorbing the water-vapour present in the atmosphere.

Expt. 27.—When a glass tumbler containing iced-water is kept on a table, fine drops of water are found on the outside of the glass. This is due to the vapour of water condensing by contact with the cold sides of the glass.

32. **Uses of the different gases found in air.**

(1) The oxygen supports animal life and makes fire to burn.

(2) The nitrogen serves to moderate the activity of oxygen. If animals were to breathe pure oxygen, their bodily frame would be over-heated and life would be impossible.

(3) The carbonic acid gas is used by plants for their growth.

(4) The ammonia supplies plants with the nitrogen necessary for their seeds; for plants have no action on the free nitrogen of the air.

(5) The water-vapour is necessary for the formation of dew and rain.

33. **Respiration is an act of oxidation.**—When animals breathe in, air goes into a fine net-work of very small tubes contained in the lungs. From thence the oxygen is carried by the blood all over the body and there combines with its waste, forming chiefly carbonic acid gas and vapour of water and producing much heat in the act of oxidation. The carbonic acid gas and water-vapour are breathed out, while the heat keeps the body warm.

34. **Expired air contains** (*a*) **carbonic acid gas** and (*b*) **aqueous vapour.**

Expt. 28.—Blow the air from the lungs through a glass tube or a piece of straw into some clear lime-water. The lime-water at once becomes milky, shewing the presence of chalk and hence that of carbonic acid gas.

Expt. 29.—Blow the air from the lungs on a cold surface for example, a plate of glass or a slate. Minute drops of water will be deposited on it.

35. **Respiration of animals compared with the burning of a candle.**—The burning of a candle and the respiration of animals are both acts of oxidation. In both cases, oxygen combines with carbon and hydrogen and produces carbonic acid gas and water. In both cases, heat is evolved by the process of oxidation. But in the burning candle, this heat is concentrated in a small space—the wick, and we see a flame; while in animals, this heat is distributed throughout the body by the circulation of blood, and consequently no flame is seen.

Note.—The heat produced in animal bodies by oxidation is called animal heat. It is on account of this heat that animals are warmer than inanimate objects.

36. **Action of plants on air.**—*In the presence of sunlight*, plants decompose the carbonic acid gas of the air and, taking carbon for their growth, give out oxygen through their leaves.

Expt. 30.—Place a bunch of green leaves in a glass vessel filled with fresh spring water. Invert this vessel into a basin of spring water and expose it to strong sun-light for an hour or two. Small bubbles will be noticed on the leaves and a quantity of gas will be seen to have collected at the top. This gas is oxygen and has been set free by the action of the leaves on the carbonic acid gas which is generally present in spring water. The carbon has been taken up by the leaves for their growth. The presence of oxygen can be found by the red-hot splinter test.

If the leaves were not exposed to the sunlight, no oxygen would be given off even after the lapse of several hours.

Note.—The presence of carbonic acid gas in spring or well-water may be shewn by the lime-water test.

37. **Action of animals and plants on air.**—Animals breathe in the oxygen of the air, breathe out carbonic acid gas mixed with some water-vapour, give off heat and are constantly burning.

Hence the air contained in a close room crowded with people contains more carbonic acid gas, more vapour of water and other impurities but less oxygen than the outside air. It is also warmer, having nearly a temperature equal to that of the animal body.

Plants breathe in carbonic acid gas, breathe out oxygen, take up the sun's light and heat for their growth, and are constantly forming materials which will burn.

Thus we see that plants produce in the air changes exactly opposite to those which animals produce. Plants purify the air, while animals constantly render it impure.

But the action of animals and plants on the air is so balanced that the composition of air remains unchanged.

This balance between the action of animal and vegetable life is illustrated by the *vivaria*—glass globes shut off from air in which water animals and plants grow by their mutual action.

Questions.

* 1. State why air is considered to be a mechanical mixture of oxygen and nitrogen and not a chemical compound of these elements.

* 2. What do you learn about the composition of air by burning phosphorus in a bell-jar over water? Does the water undergo any changes? If so, state how they may be recognized and to what they are due

* 3. How would you ascertain the composition of air? The respiration of animals is said to be an act of oxidation. Explain the meaning of this statement, name the products formed as a result of this act, and describe how the presence of each in expired air may be proved

* 4. Respiration and combustion are said to be similar processes. What evidence is there to support this statement? In what respects would you expect the air contained in a close room crowded with people to differ from the outside air? By what natural process is the air which has been altered by respiration restored to its original condition?

5. In what proportion does carbonic acid gas exist in air? Name its chief sources and explain how its proportion is kept constant in the atmosphere. How can its presence in air be detected?

* 6. How do the properties of pure air differ from those of its constituents? How do you account for the difference?

7. Name the several gases found in the air and state their uses.

* 8. Compare the process of breathing the air with the burning of a candle How may it be proved that the same substances are produced in both cases?

* 9. A piece of phosphorus is burnt in a bell-jar containing air, placed in a shallow vessel full of water, and after combustion is finished, the apparatus is allowed to stand for some time. Describe accurately what is observed to take place and what properties have been acquired by the water.

10. Describe an experiment to illustrate the nature of the changes which plants make in the air.

11. **Explain the statement "The part played by animals is exactly the opposite of that played by plants." Describe an arrangement where this fact is illustrated.**

12. **(a) Why are animal bodies warmer than inanimate objects? (b) In what respects do nitrogen and carbonic acid gas resemble each other and in what respects do they differ?**

CHAPTER IV.

HYDROGEN, *Symb: H; At. wt. 1.*

38. **Occurrence of the elements.**—This may be viewed from three standpoints :—

(1) *Whether an element occurs in the solid, liquid,* or *gaseous state.* Of non-metals, hydrogen, oxygen, nitrogen, chlorine and fluorine are gases at the ordinary temperature of the air. Bromine is a liquid, and the rest are solids. Of metals, mercury alone is liquid. The rest are solids.

(2) *Whether an element occurs abundant* or *rare.* Some elements are found abundantly, while others only very rarely, that is, in few places and in small quantities. Oxygen is the most abundant element known. For, about one-half of the solid earth, eight-ninths of water and nearly one-fifth of the air is oxygen. Silicon, nitrogen, carbon and hydrogen come next. Nearly one-fourth of the earth's crust consists of silicon. All vegetable and animal bodies are chiefly made up of carbon, hydrogen, nitrogen and oxygen. Fluorine, chromium, barium, manganese and several others are met with very rarely.

(3) *Whether an element is found combined* or *free.* Some elements occur in the combined state only, *i.e.*, in combination with other elements; as, phosphorus, chlorine, silicon, potassium. Others occur both free and combined; as, oxygen, nitrogen, sulphur, mercury. Gold occurs only free.

Note.—An element is said to occur *free* or in the *native* state, when it is met with as an element without being combined with any other substance.

39. **Occurrence of Hydrogen.**—Hydrogen is a gas. In the free state, it occurs only in small quantities upon the earth, but is supposed to exist largely in the mass of the sun. In combination with other elements, hydrogen is extremely abundant. It forms one-ninth by weight of water and is one of the chief constituents of all acids, plants and animal bodies.

40. **Preparation.—Method** (i).—Hydrogen can be produced *by the decomposition of water by passing a current of electricity through it.* (*Vide* Chap. VI.) This is known as electrolysis of water. This method of obtaining hydrogen is called a physical method, since electricity is a physical agent. Here, the gas is obtained *pure* but *in small quantities*. This method is also expensive.

Method (ii).—Hydrogen is produced *by the action of Potassium and Sodium on water at ordinary temperatures.*

Action of Potassium on water.—*Expt.* 31.—Throw a piece of potassium on water. It floats upon its surface and swims rapidly about as a molten globule. And the moment the metal touches the water, a flame of a violet colour appears round it and finally the piece disappears with a slight noise.

The chemical action that takes place may be stated thus :—Potassium sets free a part of the hydrogen from the water and combines with the oxygen and the remaining hydrogen to form alkali potash. This remains dissolved in the water. But the heat developed by the chemical action is so great that the liberated hydrogen takes fire and burns. The flame is coloured violet by the vapour of potassium.

Note.—Hydrogen burns in air with *a pale blue* flame.

Action of sodium on water.—*Expt.* 32.—**Throw a small piece of sodium on water. It swims on the surface and com-**

bines with the oxygen of the water to form alkali soda, setting free the hydrogen. No flame is seen around the metal as in the case of potassium, since the heat generated by the chemical action is not sufficient to set fire to the hydrogen generated.

If however the metal is thrown on *hot* water or a solution of starch, or if we prevent it from moving about, a flame of a yellow colour will be seen.

As potassium and sodium have great attraction for oxygen, they are kept under rock-oil which contains no oxygen.

The water on which potassium or sodium is thrown acquires alkaline properties owing to the presence of caustic potash or soda in solution Hence the water produces a soapy feeling between the fingers, and turns red litmus paper blue.

To prepare hydrogen by the action of sodium on water.

Expt. 33.—Mix a few small pieces of sodium with some mercury in a mortar so as to form an amalgam. Drop this amalgam into a basin of water, and invert over it a test-tube filled with water. The sodium will decompose the water setting free hydrogen, which ascends the tube as bubbles and displaces the water.

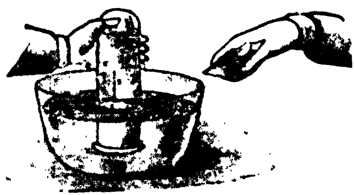

Fig. 11.

Expt. 34.—Wrap a small bit of sodium in a piece of wire-gauze. Dip it rapidly into water underneath the mouth of an inverted test-tube filled with water. Hydrogen is set free and collects in the tube displacing the water.

Method (iii).—Hydrogen is prepared *by the action of metals like iron on water at high temperatures.*

If steam is passed over red-hot iron, the oxygen of the steam combines with the iron to form an oxide known as

the magnetic oxide of iron, and hydrogen is set free. The hydrogen may be collected over water in the pneumatic trough.

Method (iv).—Hydrogen is prepared *by the action of dilute sulphuric acid on zinc.*

Expt. 35.—Take a flask containing a few zinc clippings and fitted with a cork through which are passed a long funnel-tube and a bent tube. Pour down the funnel some dilute sulphuric

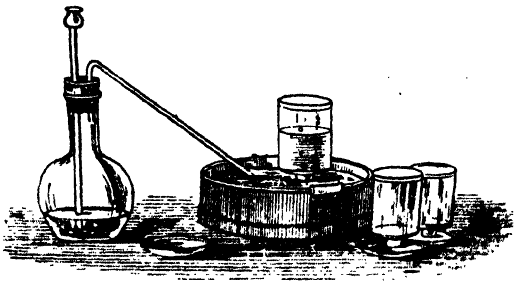

Fig. 12.

acid. The zinc dissolves in the acid forming zinc sulphate, while bubbles of hydrogen gas are given off. These bubbles are collected in bottles filled with water and placed in the pneumatic trough.

Iron filings may be substituted for zinc, and hydrochloric acid for sulphuric acid. If iron and sulphuric acid are used, iron sulphate or green vitriol is formed with evolution of hydrogen.

Note.—Caustic potash is a compound of oxygen, hydrogen and potassium. *An amalgam* is a mixture of a metal with mercury.
Zinc sulphate is a compound of zinc, sulphur and oxygen.
Sulphuric acid is a compound of hydrogen, oxygen and sulphur.
Hydrochloric acid is a compound of hydrogen and chlorine.

41. **Properties.**—1. Hydrogen is a colourless gas, having neither taste nor smell.

2. It is the lightest known substance, being $14\frac{1}{2}$ times lighter than air. Hence it is used for filling balloons.

Expt. 36.—Turn upwards the mouth of a jar filled with hydrogen and quickly light it. The hydrogen will burn with a much larger flame than when the jar is held mouth downwards.

Expt. 37.—Take a bottle filled with air and another filled with hydrogen, and hold the bottle of air above the bottle of hydrogen as in Fig. 13. In a few seconds it will be found that the light hydrogen has passed up into the upper bottle and displaced the air. For if a light is applied to the top bottle with its mouth downwards, the hydrogen will take fire and burn, with a slight report from admixture of air. Thus, we may pour a jar of hydrogen upwards into another.

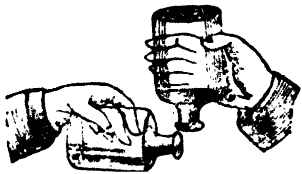

Fig. 13.

Expt. 38.—Place a vessel containing hydrogen mouth upwards and uncovered; the gas escapes in a short time, and the vessel becomes filled with common air. But if the mouth is held downwards, it remains in the vessel for a longer time.

3. Hydrogen is very slightly soluble in water.

4. It is inflammable, and burns in air with a pale blue flame giving out much heat; but it is not ordinarily a supporter of combustion.

Expt. 39.—Push a burning candle into a jar of hydrogen. It lights the gas at the mouth, but is put out within the jar. When taken out, the candle is rekindled by the flame of the burning hydrogen.

5. A mixture of oxygen and hydrogen violently explodes, when a light is applied to it.

Test for Hydrogen.—*Hydrogen, when lighted, burns in air with a pale blue flame forming water.*

42.—**When hydrogen burns in air, *nothing but* pure water is formed.**

Expt. 40.—When a dry, cold, glass is inverted over a jet of hydrogen that is burning, small drops of water are deposited on the inside.

If the gas is burnt in a jar, no milkiness is produced when clear lime-water is poured into it and shaken. Thus, we see that no carbonic acid gas is produced as in the case of a burning candle.

43. **Uses.**—Hydrogen is used (1) to fill balloons, on account of its lightness, (2) to reduce some metallic oxides, on account of its affinity for oxygen, and (3) to fuse platinum by the help of the oxy-hydrogen blowpipe, on account of the great heat produced when it burns with oxygen.*

44. **Difference between steam** and **a mixture of Hydrogen and Oxygen.**—(1) When heated, a mixture of oxygen and hydrogen explodes, forming steam; but on heating, steam only expands and does not undergo any change in its composition. (2) The mixture becomes condensible only under extremely high pressure and low temperature; whereas steam is easily condensible by cold. (3) The mixture is not absorbed by hygroscopic substances such as sulphuric acid or calcium chloride, while steam is readily absorbed by them. (4) The mixture absorbs but little radiant heat; whereas, steam absorbs

much radiant heat. (5) Steam contains its constituents in fixed proportions by weight; but the mixture not necessarily.

Questions.

* 1. Describe the changes which occur and name the products formed, when a piece of potassium is thrown on water. What new properties does the water acquire in consequence of this action? Mention two ways by which this property can be recognised.

* 2. A piece of sodium is placed on the surface of hot water contained in a vessel. Describe accurately what is observed to take place and what properties have been acquired by the water.

* 3. Describe a chemical method of preparing hydrogen from water.

4. Name the most important compound of hydrogen. If you desire to obtain the gas in as pure a condition as possible, what method would you adopt?

* 5. What are the names of the compounds which hydrogen forms with (*a*) oxygen, (*b*) chlorine, and (*c*) nitrogen?

6. If you desire to prepare hydrogen in large quantities, what method would you adopt? By what test would you identify the gas? Name its chief properties and state how the gas is collected.

7. Describe experiments to show that (1) hydrogen is lighter than air; (2) when hydrogen burns in air, nothing but pure water is formed.

* 8. State what you would *see* if the following experiments were performed before you, and write the equations representing the re-actions which would occur.

(1) Sulphuric acid is poured over some pieces of granulated zinc.
(2) A clean cut piece of sodium is thrown on water.
(3) A clean cut piece of potassium is thrown upon water.

* 9. Describe clearly what takes place when

(*a*) steam is passed over red-hot iron;
(*b*) dilute sulphuric acid is poured on iron filings;
(*c*) a burning candle is introduced into a jar of hydrogen;
(*d*) a current of electricity is passed through acidulated water.

10. Explain why (1) potassium and sodium are kept under rock-oil, and (2) a mixture of hydrogen and oxygen explodes when lighted.

* 11. In what respects does a mixture of oxygen and hydrogen differ from the chemical compound of these bodies?

* 12. How do the properties of steam differ from those of its constituents? (*b*) How do you account for

Answer. (a) Hydrogen is a combustible gas, oxygen a supporter of combustion; but steam is neither. (2) Hydrogen has a density of 0·067, oxygen 1·1; while steam, 0·65. (3) Steam is readily condensible by cold; but both hydrogen and oxygen are condensible only under high pressure and great cold. (4) Steam absorbs much radiant heat; but hydrogen and oxygen do not. (5) Steam is readily absorbed by substances such as calcium chloride and sulphuric acid; while neither oxygen nor hydrogen is. (b) Steam is a chemical compound.

CHAPTER V.

CHEMICAL NOTATION.

45. **Chemical symbols** and **their meaning.**—Instead of writing the full name of each element and compound, the chemist uses a kind of short-hand. Each element, or rather a definite proportion of it is represented by a symbol and this is the first letter or the first letter followed by an additional distinguishing letter of the English or the Latin name. Thus, C stands for carbon; K for potassium (Lat. Kalium); Si for silicon, and Mg for magnesium. The single letter is always a capital letter. When two letters are used, the first is a capital and the second a small letter.

The symbol does not merely stand for the element in question but it represents a definite weight of it, i.e., the smallest proportion by weight in which the element is found to combine with others. Thus, the symbol O does not merely express the name of the element oxygen but 16 parts by weight of oxygen, which is the combining weight of the element. Similarly, C stands for 12 parts by weight of carbon. Using a symbol, when no definite quantity is meant, is therefore a highly objectionable practice.

The combining weight of an element is *the number representing the smallest proportion by weight in which that element*

combines with another. **Hydrogen being the lightest substance known, its combining weight is taken as the standard of comparison and is accordingly unity. Hence when we say that the combining weight of oxygen is 16, we mean that the smallest quantity by weight of oxygen which can enter into chemical combination is 16 times as great as the smallest quantity of hydrogen (H) which can also enter into combination.**

Note.—The combining weights are sometimes called **atomic weights.** *An atom* (Gk. a = not, temno = I cut) is defined as the smallest indivisible particle of an element which can enter into chemical combination with another element, or which can be liberated from a chemical compound. Hence it is also said that the symbol O stands for the weight of an atom of oxygen.

46. A chemical formula and **its significance.**—*A chemical formula is the representation of a chemical compound by means of symbols.* This is done by placing the symbols of the elements composing the compound side by side with suffixes indicating the number of atoms of each.

Here are the formulæ of some of the compounds mentioned in the preceding chapters :—Water, H_2O ; Carbonic acid gas, CO_2 ; Chalk, $CaCO_3$; Sulphuric acid, H_2SO_4 ; Caustic Soda, $NaOH$; Zinc sulphate, $ZnSO_4$; Magnetic Oxide of iron, Fe_3O_4. The quantity of any compound which is represented by its formula is spoken of as a molecule. When a number of molecules is to be represented, the particular number is prefixed, as $8\,H_2SO_4$ which is read as eight molecules of sulphuric acid.

What a chemical formula teaches us.—1. A chemical formula tells us *the elements* of which a compound is composed. Take, for instance, the formula H_2O. We learn from it that water is composed of hydrogen and oxygen.

2. It tells us the *number of atoms* of the elements of which the compound is composed. Thus, from H_2O we learn that water contains two atoms of hydrogen and one atom of oxygen.

3. It tells us *the proportion* in which the constituent elements are contained in the compound. Thus, we

learn from the formula H_2O that water is composed of oxygen and hydrogen in the ratio of 1 : 2 by volume, and 16 : 2 by weight.

4. It represents *one* molecule of the given compound and gives its molecular weight. Thus, H_2O represents one molecule of water and tells us that the molecular weight of water is $(2 + 16 =)$ 18.

Note 1.—*A molecule* is the smallest quantity of a compound or an element supposed to be capable of existing by itself, having all the properties of the substance. All physical changes are supposed to take place between molecules, and chemical changes between atoms.

Note 2.—The molecular weight or the weight of a molecule is the sum of the weights of the atoms of which it is composed; for, molecules are made up of atoms.

47. **Chemical equations** and **their uses.**—A chemical equation is the representation of a chemical change in a shortened form by means of symbols. For example, the chemical change that takes place when potassium is thrown on water is represented by the following equation :—

Potassium.		Water.		Alkali Potash.		Hydrogen.
K_2	+	$2\,H_2O$	=	$2\,KOH$	+	H_2.

The equation means that one molecule or 78 parts by weight of potassium *acting chemically* on two molecules or 36 parts by weight of water *yields* two molecules or 112 parts by weight of alkali potash *and* one molecule or 2 parts by weight of hydrogen.

Note.—In a chemical equation, the substances that we have before the chemical change are represented on the left-hand side, and the substances that we have after the chemical change, on the right-hand side.

Similarly, the chemical change that takes place when sodium is thrown on water is represented by the equation :

Sodium.		Water.		Alkali Soda.		Hydrogen.
Na_2	+	$2\,H_2O$	=	$2\,NaOH$	+	H_2.

What a chemical equation teaches us.—Take an example. We prepare hydrogen by the action of dilute sulphuric acid upon zinc. The change which takes place is represented by the equation :—

Before the change.				After the change.		
Zinc	*and*	Sulphuric acid	*yield*	Zinc Sulphate	*and*	Hydrogen.

$$
\begin{array}{ccc}
Zn + H_2SO_4 & = & Zn\,SO_4 + H_2 \\
65 + \underbrace{2\times 1 + 32 + 16\times 4} & = & \underbrace{65 + 32 + 4\times 16} + \underbrace{2\times 1}. \\
\underbrace{65 + \quad 98}_{163} & = & \underbrace{161 \quad + \quad 2}_{163}
\end{array}
$$

1. A chemical equation tells us *what substances undergo chemical change and what substances result from it.* Thus, we learn from the above equation that sulphuric acid acting upon zinc produces zinc sulphate and hydrogen.

2. It tells us *what weights of substances undergoing chemical change yield what weights of fresh substances.* Thus, we learn from the above equation that 65 parts by weight of zinc and 98 parts by weight of sulphuric acid yield 161 parts by weight of zinc sulphate and 2 parts by weight of hydrogen.

3. It tells us that, when chemical changes take place, *there is only a difference of arrangement of the atoms, and no substance which was not there before the change is afterwards present.* Thus, in the above equation, the one atom of zinc has replaced the two atoms of hydrogen in sulphuric acid to form zinc sulphate and hydrogen.

4. It tells us that *nothing is lost* when chemical changes take place. Thus, from the numbers which the several symbols in the above equation represent, we learn that the zinc sulphate and the hydrogen which we get weigh exactly as much as the zinc and sulphuric acid we took.

Hence the uses of chemical equations are (1) to represent chemical changes in a shortened form by means of symbols; (2) to enable us to calculate the weight of materials that should be used in order to get a given weight of a required substance; (3) to prove that in chemical changes we have neither gain nor loss of matter.

48. Chemical Arithmetic.

(1) How many grammes of oxygen can be obtained by heating 100 grammes of red oxide of mercury?

The equation representing the chemical change is :—

$$
\begin{array}{ccccc}
2\,HgO & = & 2\,Hg & + & O_2 \\
\underbrace{2\,(200+16)}_{432} & = & \underbrace{2 \times 200}_{400} & + & \underbrace{16 \times 2}_{32}
\end{array}
$$

From the equation, we learn that

For every 482 grammes of the oxide, we get 32 of oxygen.

$\therefore$ for every 1 gramme, we get $\frac{32}{432} = \frac{2}{27}$ of oxygen.

$\therefore$ for every 100 grammes, we get $\frac{2}{27} \times \frac{100}{1} = \frac{200}{27} = 7\frac{11}{27}$ grammes of oxygen. **Ans.**

(2) Find the weight of steam and iron required to generate 40 lbs. of hydrogen.

The equation representing the change is :—

$$
\begin{array}{ccccccc}
\text{Steam.} & & \text{Iron.} & & \begin{array}{c}\text{Magnetic}\\ \text{oxide of iron.}\end{array} & & \text{Hydrogen.} \\
4\,H_2O & + & 3\,Fe & = & Fe_3O_4 & + & 4\,H_2 \\
\underbrace{4\,(1 \times 2 + 16)}_{72} & + & \underbrace{3 \times 56}_{168} & = & \underbrace{(56 \times 3 + 16 \times 4)}_{232} & + & \underbrace{4 \times 2 \times 1}_{8}
\end{array}
$$

Now, from the equation we learn that,

to get 8 lbs. of hydrogen, we require 72 lbs. of steam and 168 lbs. of iron.

$\therefore$ to get 1 lb. of hydrogen, we require $\frac{72}{8}$ lbs. of steam and $\frac{168}{8}$ lbs. of iron.

$\therefore$ to get 40 lbs. of hydrogen, we require $\frac{72}{8} \times \frac{40}{1}$ lbs. of steam and $\frac{168}{8} \times \frac{40}{1}$ lbs. of iron.

That is, 360 lbs. of steam, 840 lbs. of iron. **Ans.**

(8) **Find the percentage composition of nitric acid.**

The formula is HNO_3

$\therefore$ **the molecular weight is $1 + 14 + 48 = 63$.**

Now, for every 63 parts by weight of nitric acid, we have 1 of hydrogen, 48 of oxygen, and 14 of nitrogen.

$\therefore$ for every 100 parts by weight of nitric acid, we have $\frac{1}{63} \times \frac{100}{1}$ of H; $\frac{48}{63} \times \frac{100}{1}$ of O; $\frac{14}{63} \times \frac{100}{1}$ of N.

i.e., $1\frac{37}{63}$ of hydrogen, $76\frac{4}{21}$ of oxygen and $22\frac{2}{9}$ of nitrogen.

Hydrogen	..	1·59
Oxygen	..	76·19
Nitrogen	..	22·22
		100·00 **Ans.**

Note.—The percentage composition is merely the statement of the relative weights of each of the constituents in 100 parts of the compound.

Questions.

1. How is the symbol of an element formed? For what does the symbol 'Mg' stand?

2. What is a chemical formula? What does it signify?

• 3. (*a*) What quantity of water is represented by the formula OH_2?

(*b*) Explain how the composition by weight is expressed by the formula of a compound.

4. Find the molecular weight of sulphuric acid. How does a molecule differ from an atom?

• 5. For what purposes are chemical equations employed and what information do they convey?

• 6. Complete the equation $Zn + H_2SO_4 =$

Calculate the weight of zinc and of sulphuric acid required to produce four grains of hydrogen.

• 7. Show how you would use a chemical equation to ascertain the weight of sulphuric acid required to dissolve 100 lbs. of zinc and the weight of hydrogen thus produced.

8. Write in words

(*a*) $Fe + H_2SO_4 = FeSO_4 + H_2$

(*b*) $Zn + 2\,HCl = ZnCl_2 + H_2$

• 9. **What is meant by the combining weight of an element? Explain why the combining weight of oxygen is said to be 16.**

10. **Find the percentage composition of Ferrous Sulphate and** ...

11. Write equations for the following reactions:
   (a) The action of dilute Sulphuric acid upon iron filings.
   (b) The decomposition of steam by red-hot iron.
   (c) The action of sodium on hot water.
   (d) The action of dilute hydrochloric acid on zinc clippings.

12. Explain the meaning of the following equation:—

Iron		Hydrochloric acid		Ferric chloride		Hydrogen
Fe	$+$	$2\,HCl$	$=$	$FeCl_2$	$+$	H_2.

* 13. Calculate the weight of hydrogen and iron oxide which will be produced when 200 grammes of iron are heated in a current of steam, if the oxide produced has the formula Fe_3O_4

CHAPTER VI.

Composition of Water.

49. **Water** is a chemical *compound* of oxygen and hydrogen in the proportion of 1 : 2 by *volume*, and 16 : 2 by *weight*.

The composition of any compound may be determined either by analysis or by synthesis. *Analysis* is the decomposition of a compound into its component elements. *Synthesis* is the building up of a compound by bringing together its component elements.

The expression **Qualitative** composition is used to denote the elements of which a compound is built up, **Quantitative** composition to denote the proportion by weight as well as by volume in which the compound contains its constituent elements.

50. **Composition of water by volume.**—(1) *Analysis of water.* The composition of water by volume is found by decomposing water by a current of electricity, when, for every two volumes of hydrogen one volume of oxygen is produced.

Expt. 41.—Take a funnel-shaped glass, closed at the bottom with a cork through which two platinum wires pass. Pour into the funnel some acidulated water. Fill two test tubes of equal size with water, and invert them over the ends of the wires in the glass. Now, connect the other ends of the wires with the pole wires of a Grove's battery. A current of electricity at once passes through the water and decomposes it. Hence bubbles of gas appear around the platinum wires and rise in the two tubes displacing the water.

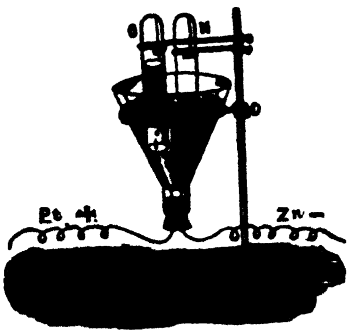

Fig. 14

It will be observed that twice as much gas collects in the one tube as in the other. The gas produced in smaller quantity is oxygen, as it will be found to rekindle a red-hot splinter of wood introduced into it. The other gas is hydrogen, as it will be found to burn with a pale blue flame, when lighted.

Thus, we conclude that water is composed of one part by *volume* of **Oxygen** and 2 parts of **Hydrogen.**

(ii) Synthesis of water.

Expt. 42.- Send an electric spark into a mixture of two volumes of hydrogen and one of oxygen. The entire gaseous mixture is changed with an explosion into water, leaving no residue. If we take of either gas a little more than the required proportion, the excess remains uncombined.

51. **The composition of water by weight.**—The composition of water by weight is determined by passing a current of pure and dry hydrogen over a known weight of heated black oxide of copper. The hydrogen combines with the oxygen of the copper oxide to form water and

the black oxide losing its oxygen is left behind as a bright red powder of metallic copper. From the weights of the copper and the water formed, we can easily find the proportion by weight of oxygen and hydrogen in water. Thus, if the weights of the copper oxide, copper, and water are 82 grs., 50 grs. and 36 grs., respectively, the 36 grs. of water formed contains 32 grs. of oxygen and 4 grs. of hydrogen. That is, water is composed of 1 part of hydrogen by weight to every 8 parts of oxygen.

Expt. 43.—Take a bulb-tube of hard glass **A** containing black oxide of copper (CuO), and a U-tube **B** filled with dry calcium chloride ($CaCl_2$). Weigh them both *separately*, and note down their weights.

Next, take a flask **C** containing zinc for generating hydrogen, a wash-bottle **D** containing strong sulphuric acid for drying the hydrogen, and a glass tube **E** containing calcium chloride for drying the gas still further.

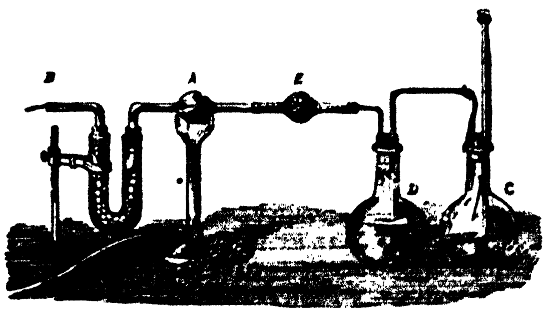

Fig. 15.

Now, arrange the whole apparatus as shown in the figure, and pour down the funnel-tube some dilute sulphuric acid upon the zinc clippings. Hydrogen gas is generated, and passing through the whole apparatus expels all the air, and

gets thoroughly dried as it bubbles through **D** and **E**. When the air has all been expelled, heat the copper oxide in the bulb-tube by a lamp.

The hydrogen combines with the oxygen of the copper oxide to form water, and the black oxide losing its oxygen is left behind as a bright red powder of metallic copper.

Black oxide of copper.		Hydrogen.		Water.		Copper.
CuO	+	H_2	=	H_2O	+	Cu

The water formed by the union of hydrogen with the oxygen of the copper oxide is absorbed by the calcium chloride in the tube **B**.

Again, weigh the bulb-tube **A** and the U-tube **B**. It will now be found that the tube **A** *weighs less*, having lost the weight of oxygen, and the tube **B** *weighs more*, having gained the weight of water formed in the re-action.

We have

(i) Wt. of the tube **A** before expt. is	1,000 grs.
,, ,, after expt. is	960 grs.
∴ the loss of wt. due to the escape of oxygen is	40 grs.
(ii) Wt. of the tube **B** before expt. is	800 grs.
,, ,, after expt. is	845 grs.
∴ the gain of wt. due to the water formed is	45 grs.

So we see that 45 grs. of water contains 40 grs. of oxygen. Since water contains nothing but oxygen and hydrogen, the weight of hydrogen in the water must be $45 - 40 = 5$ grs.

Thus, we find that 45 parts by weight of water contain 40 parts by weight of oxygen and 5 parts by weight of hydrogen; or to *2 parts of hydrogen by weight, water contains 16 parts of oxygen.*

52. **Properties of water.**—Water exists in nature in three forms: in the solid form as ice, in the liquid state as water, and in the gaseous form as steam.

(*a*) *Physical properties:*—1. Pure water has no taste, smell or colour. Deep water appears blue.

2. It is liquid at the ordinary temperature, but freezes at 0°C. and becomes steam at 100°C. under normal pressure.

3. It is more than 800 times heavier than air, and has a maximum density at 4°C.

4. It is almost incompressible.

5. It is a bad conductor of heat and a good conductor of electricity.

(*b*) *Chemical properties*: 1. In crystals, water serves to keep their crystalline structure.

2. Water is the best solvent. A greater number of substances dissolve in it than in any other liquid. Thus, it greatly aids chemical change by bringing into close contact the substances which are to act chemically upon one another.

3. It is decomposed by many metals. Thus, potassium, sodium and calcium decompose it *in the cold*; iron, zinc and magnesium *when red-hot*; while zinc and iron *by the help of an acid*. On the other hand, gold, silver, mercury and copper have *no action* whatever upon water.

Questions.

1. Explain the two methods by which the compound nature of a substance may be determined. Describe two *simple* experiments illustrative of your answer.

2. Explain how the effect of sending heat into water differs from that of sending a current of electricity into it

* 3. What is the composition of water by weight and by volume? By what experiments can the relative proportion of its constituents be demonstrated?

4. Name the three different states in which water is known to us How may water be decomposed without the application of chemical re-agents?

* 5. Describe how you would ascertain the qualitative composition of water? Having proved that water contains both oxygen and hydrogen, how would you show the proportion in which these elements are combined, by weight as well as by volume?

• 6. What action takes place when hydrogen is passed over heated black oxide of copper? Describe how the re-action is used for ascertaining the relative weights of hydrogen and oxygen in water.

• 7. Describe the changes which occur when a stream of dry hydrogen is passed over heated black oxide of copper. If 158 grammes of copper oxide are heated, what weight of hydrogen is necessary to reduce the oxide completely?

8. When 52·821 grammes of black oxide of copper were heated in contact with hydrogen, the residual copper weighed 41·986 grammes and 12·197 grammes of water obtained. Find the percentage composition of water.

• 9. Explain how a chemical equation is used to ascertain the weight of black oxide of copper required to convert 10 grammes of hydrogen into water.

10. Describe the behaviour of metals on water. Give some of the properties of water.

CHAPTER VII.

NATURAL WATERS.

53. **Rain water.**—Rain-water is the purest form of water occurring in nature. By the sun's heat, the water of rivers, lakes and oceans is evaporated, and ascends into the sky in the form of vapour or invisible steam. At a certain height, these vapours losing their heat become converted into visible clouds which are carried by the wind all over the globe. When these clouds meet cold air, they are condensed and fall down as drops of rain. Rain-water is therefore *distilled water.*

Rain-water, however, differs from distilled water in containing a small quantity of air and carbonic acid gas dissolved in it during its passage through the air. But both distilled water and rain-water leave no residue when evaporated, and *at once* produce a *lather* with soap solution. The presence of carbonic acid gas in rain-water can be shown by the lime-water test.

54. **Spring-water.**—Spring-water is rain water which

has passed through soils and rocks. Thus, it contains several substances and gases in solution. According to the nature of the soil through which the water passes, spring-waters may contain in small or large quantities one or more of the following substances: common salt, chalk, gypsum, magnesium carbonate, and Epsom salts. Further, nearly all springs contain a very small quantity of silica or sand in solution. Silica (SiO_2) dissolves in hot water containing an alkali, such as potash in solution.

The waters of town-wells generally contain also traces of organic matter, ammonia, more or less of the nitrates and the unhealthy nitrites of calcium and of sodium.

Spring or river water distinguished from rain-water.

Expt. 44.—Boil down some clear spring or filtered river water in a clean porcelain dish so as to drive off all the water. We shall always find that *some solid residue* is left. Boil down some distilled water. *No solid residue* will remain.

55. **River-water.** Rain-water flowing on the surface of the earth and gathering into large quantities forms *river-water*. As it dissolves and washes away many substances from the soil, when flowing over the surface, it becomes more and more impure.

The nature and quantity of the impurities depend upon the nature of the soil through which the river passes and on the kind of organic matter derived from surface drainage. Water (as of the Dee in Scotland) passing through granite and other hard rocks cannot take up in solution any substance and is nearly pure. Water flowing over rocks of chalk (as of the Thames) or of gypsum (as of the Trent), or of beds of rock-salt contains these substances in solution.

Suspended impurities are also found in river-waters. These consist chiefly of clay, sand, animalcules and organic matter such as tissues of vegetable and animal matter.

So river-water is turbid and is always found to be full of fine muddy particles. It can therefore be easily distinguished from spring-water, which is clear and free from muddy particles in suspension.

56. Organic impurities in water tested.

Expt. 45.—Add a few drops of sulphuric acid to such water. Then pour some potassium permanganate solution into it. The colour of the solution will be found to change from purple into dull-red in an hour or two.

57. **Drinking-water.**—For drinking purposes, water should be obtained from as pure a source as possible. It should be clear and colourless, and as free as possible from organic impurity arising from sewage contamination or contact with decaying animal or vegetable matter. To secure this, drinking water should be boiled and finally filtered.

The tri-pot filter arrangement should be used in every household which desires wholesome water for drinking. It consists of three earthen pots, one above the other in a stand. The lowest receives the filtered water. In the other two pots are made three or four small holes in which pieces of straw are inserted. The top-most contains well-washed river sand and the middle one, mixture of clean sand and fresh charcoal.

Boiled water is poured in the top-most pot. Most of the impurities undergo decomposition by the boiling and are thereby rendered harmless, while the suspended impurities are kept back by the sand. The oxygen encased between the grains of sand and contained within the pores of the charcoal further acts upon some of the dissolved injurious matter and oxidizes them into harmless compounds. When the water falls in drops through the air from the first pot to the second and from the second to the third, some air gets dissolved in it. This completes the decomposition of dissolved organic matter and to a great extent restores to the water the taste it had lost on being boiled.

Note.—The sand, the pieces of straw, and the charcoal should be renewed as often as possible, and the pots well cleaned and dried at times.

58. **Sea-water.**—Sea-water is the most impure water found in nature. This is owing to the sea constantly having dissolved and suspended matter carried into it from the land, and pure water being carried away by evaporation.

Sea-water is largely loaded with common salt. It also contains a large number of other salts such as magnesium chloride, magnesium sulphate and calcium sulphate. 100 grs of sea-water contain about $2\frac{3}{4}$ grs. of common salt; while other substances in solution amount to only $\frac{7}{10}$ of a grain.

Test for salt water. -*Expt.* 46.—Add a few drops of silver nitrate solution to sea-water or water containing the slightest traces of common salt. The liquid becomes milky, a white precipitate of silver chloride being formed.

Common salt.		Silver nitrate.		Silver chloride.		Sodium nitrate.
$NaCl$	+	$AgNO_3$	=	$AgCl$	+	$NaNO_3$.

59. **Hard and soft water.** Water is said to be *hard*, when soap does not *at once* form a lather with it, but a sediment or curd is produced. It is said to be *soft*, when it readily forms a lather or froth with soap. Rain water and distilled water are soft; while sea-water, most spring and river-waters are hard.

The chief cause of hardness is the presence of the salts of calcium or the salts of magnesium, such as chalk ($CaCO_3$), gypsum ($CaSO_4$), Epsom salts ($MgSO_4$) and magnesium carbonate ($MgCO_3$) in solution.

60. **Test for hardness of water.**

Expt. 47.—Add a few drops of clear soap solution to a specimen of water and shake the liquid. If a curd or precipitate is produced, the water is hard, but if a lather is *at once* formed, it is soft.

It should be remembered that, if a sufficient quantity of soap solution is added to hard water, a froth will ultimately appear. Soap solution is made by shaking up a few shavings of soap with hot water and filtering the solution.

61. The hardness of water is of two kinds.

(i) *Temporary hardness of water* is chiefly caused by the presence of chalk or magnesium carbonate in it. These salts are insoluble in pure water but dissolve to a considerable extent in water containing carbonic acid gas in solution.

River and spring-waters generally contain chalk in solution, because rain-water which chiefly constitutes them has carbonic acid gas in solution.

Expt. 48.—When we blow the expired air into some clear lime-water, it becoms milky by the formation of chalk; but if we continue to blow for about five minutes, the milkiness begins to disappear and the water becomes clearer, the precipitated chalk greatly dissolving in the water containing carbon di-oxide in solution. Filter the liquid. The clear solution will be found by the soap test to be quite hard.

(ii) *Permanent hardness of water* is caused by the presence of gypsum or Epsom salts.

62. Methods of softening hard waters.

(i) The temporary hard water becomes soft, if it is deprived of the carbonic acid gas which holds the chalk or the magnesium carbonate in solution. This is done in two ways:

(*a*) *By boiling the water.*

(*b*) *By adding lime-water*

Expt. 49.—Boil some hard chalk water in a flask. All the carbonic acid gas which holds the chalk in solution will be driven off, and the chalk is thrown down as a white powder. Filter the boiled water. It will be found by the soap test that the water is no longer hard but has been softened by boiling.

Note.—The crust often found at the bottom or sides of kettles and boilers is simply the deposit of chalk which slowly separates out on boiling hard chalk water.

Expt. 50.—Add some lime-water to hard chalk-water. The lime combines chemically with carbonic acid gas present, forming chalk. The water, deprived of carbonic acid gas, can now

no longer hold in solution the chalk originally contained in it, and this also is precipitated. So the water becomes soft.

Lime water. Hard chalk water. Chalk. Water.

$$CaO, 2H_2O + \overbrace{CO_2 + CaCO_3 + H_2O} = 2CaCO_3 + 3H_2O.$$

This latter method is usually employed when hard chalk-water is to be softened *on a large scale*.

Note.—A solution of caustic potash may be used instead of lime-water, but caustic potash is more costly.

Hard chalk water. Caustic potash. *Soluble* potashes. *Insoluble* chalk. Water.

$$\overbrace{H_2O + CO_2 + CaCO_3} + 2KOH = K_2CO_3 + CaCO_3 + 2H_2O$$

Caustic potash combines with carbonic acid to form potassium carbonate; this remains dissolved in the water. The chalk is precipitated, carbonic acid holding it no more in solution.

(ii) Hard gypsum water cannot be softened by boiling the water. Hence it is called permanent hard water. It is softened by the addition of washing soda (Na_2CO_3). Washing soda acting upon gypsum produces calcium carbonate and sodium sulphate. The former is removed by filtration; the latter remains in the water, but does not make the water hard.

Gypsum. Washing Soda. Chalk. Sodium Sulphate.

$$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$$

Questions.

1. What is the purest form of water found in nature? How is it formed?

2. What reasons have we for saying that rain-water is distilled water?

* 3. Mention the principal substances which ordinary river water contains in solution. What substances particularly injurious to health often occur in the river water or shallow well-water of towns? Describe some simple process (such as could be used in any household) by means of which such dangerous waters could be made safer to drink.

4. How do rain-water, spring-water, river-water and sea-water differ from each other? Describe any simple experiments by which they may be identified.

5. What are the essential qualities of good drinking water?

* 6. Give two tests by which distilled water can be distinguished from river or well water.

7. How can you tell whether a water is 'soft' or 'hard'? State the constituents to which the temporary and permanent hardness of water are respectively due. How are hard waters softened?

* 8. Sea-water and rain water are separately (*a*) mixed with soap solution, (*b*) mixed with silver nitrate solution, and (*c*) evaporated State and explain what happens in each case.

9. Explain fully what takes place (1) when a current of carbon di-oxide is passed through lime-water, (2) when soap solution is added to hard water.

* 10. Explain fully why some hard waters are softened by boiling, while others are not.

11. Explain the circumstances under which the addition of (*a*) washing soda, (*b*) lime-water renders a water soft, and state why they do so.

12. Calculate the weight of silver nitrate required to precipitate 50 grs. of common salt in solution; also the weight of silver chloride produced by the re-action.

CHAPTER VIII.

OXYGEN: *Symb. O; At. Wt. 16.*

63. **Occurrence.**—Oxygen is a gas, and exists both *free* and *combined*. It is the most abundant and widely distributed element in nature. In the free state, it occurs in the atmosphere mechanically mixed with about four times its volume of nitrogen. Combined with other elements, it constitutes eight-ninths by weight of water and nearly one-half by weight of the earth's solid crust.

64. **Preparation.**—*Pure* oxygen is got by heating red oxide of mercury or chlorate of potash, or by the electrolysis of water. But when required *on a large scale*, oxygen is obtained by heating chlorate of potash mixed with black oxide of manganese.

Expt. **51.—Put a little of the powder called red oxide of mercury in a hard glass tube fitted with a cork and a delivery tube, and heat it in the flame of a spirit lamp. The red powder first darkens in colour and is then decomposed by the action of heat into mercury and oxygen. The evolved oxygen may be collected over water in the pneumatic trough; while the mercury condenses in the form of metallic globules upon the cooler parts of the tube inside.**

Mercuric oxide.		Mercury.		Oxygen.
$2\,HgO$	=	$2\,Hg$	+	O_2
$2\,(200 + 16)$	=	400	+	32

Note 1.—Two molecules of the oxide are taken so as to get an entire molecule of oxygen.

Note 2.—Out of 432 parts by weight of mercuric oxide which is very costly, we get only 32 parts by weight of oxygen. Hence this method will be found to be very expensive, where oxygen is required on a large scale.

(ii) For experimental purposes, oxygen is best prepared by heating a mixture of potassium chlorate and black oxide of manganese.

Expt. 52.—Take some powdered chlorate of potash and mix it with enough manganese dioxide to make it black. Gently heat the mixture in a flask furnished with a cork and a long tube. Potassium chlorate is decomposed into oxygen and potassium chloride. The gas, as it escapes at the end of the tube, may be collected over water in the trough.

$$2\,KClO_3 + MnO_2 = 2\,KCl + MnO_2 + 3\,O_2$$

The black oxide of manganese undergoes no change whatever, but merely helps the decomposition. When chlorate of potash is heated alone, it undergoes decomposition at a high temperature of about 400°C.

Note.—If chlorate of potash or red oxide of mercury or any substance which gives up oxygen be heated with carbon or hydrogen,

the liberated oxygen combines with that element to form an oxide. Thus,

$$2\,HgO + C = 2\,Hg + CO_2$$
$$HgO + H_2 = Hg + H_2O$$
$$2\,KClO_3 + 3C = 2\,KCl + 3CO_2$$

65. **Properties.**—1. Oxygen is a colourless gas, having no taste or smell.

2. It is slightly heavier than air, its Sp. Gr. being 1·1.

3. It is slightly soluble in water.

4. Oxygen is a supporter of combustion and is not generally combustible.

5. It is the only gas which can support respiration and consequently animal life.

6. Oxygen is remarkable for its great chemical activity. Even at the ordinary temperature, it is able to combine with such elements as phosphorus, potassium, sodium and iron. At high temperatures, it combines with all the elements except *fluorine*, to form oxides.

7. Substances which slowly burn in air burn in oxygen with increased rapidity and brilliancy. Many substances that do not burn in air burn with violence in oxygen.

Expt. 53.—Plunge a burning candle into a jar of oxygen. It burns with an increased brilliancy, producing steam and carbon di-oxide.

Expt. 54.—A small quantity of sulphur, melted and allowed to burn in a spoon, burns in oxygen with a brilliant blue flame forming sulphur di-oxide (SO_2).

Expt. 55.—Ignite a small piece of dry phosphorus in a spoon. Pass it into a bottle of oxygen. It burns with dazzling brightness in the gas, forming white fumes of phosphoric anhydride ($P_2\,O_5$).

Expt. 56.—Introduce a piece of red-hot charcoal into a jar of oxygen. It burns brilliantly in oxygen forming carbon-di-oxide.

Expt. 57.—Take a fine iron-wire and dip one end of it into melted sulphur. A little of the sulphur will adhere. Now ignite the sulphur, and while it is burning, pass it quickly into a jar of oxygen. The burning sulphur heats the iron wire to redness, and then the iron itself commences to burn brilliantly, giving out sparks of iron oxide (Fe_3O_4).

Test for oxygen.—*A red-hot splinter of wood, introduced into a jar of oxygen, immediately bursts into flame.*

Note.—The uses of oxygen dissolved in water.

(*a*) The oxygen dissolved in water serves for the breathing of fishes. Fishes pass the water through their gills and take the dissolved oxygen for breathing in. When the water is boiled, the oxygen is driven out. Hence a live-fish placed in water boiled and cooled without exposure to air, dies from want of oxygen.

(*b*) It gives taste to the spring or river water. Boiled water is insipid, because the oxygen has been driven out.

(*c*) It decomposes vegetable and animal impurities that are generally present in river or canal waters and forms with them harmless compounds. Thus, it makes running water wholesome.

66. Metals become heavier by oxidation.

Expt. 58.—Dip the ends of a horse-shoe magnet into iron filings. These will stick to the magnet forming a kind of small brush. Hang the magnet to one end of the beam of a balance, and counterpoise it by weights at the other. If we now set fire to the filings, they will burn, combining with the oxygen of the air to form iron-rust or oxide of iron. And the rust will be found to be heavier than the filings.

Expt. 59.—Weigh a small quantity of mercury. Heat it in air nearly to its boiling temperature. It will gradually change to a red powder. If the powder is now weighed, it will be seen that it weighs more than the shining mercury, having combined with the oxygen of the air.

67. Oxygen and Hydrogen compared.

(i) *Points of similarity.*

Both are transparent, colourless, inodorous gases.

(ii) *Points of dissimilarity.*

1. Oxygen combines easily with carbon, sulphur, phosphorus, and iron. It is a difficult matter to get any of these

elements to combine directly with hydrogen. Further, substances which combine readily with hydrogen do not combine readily with oxygen; *e. g.*, fluorine, chlorine.

2. Oxygen is 16 times as heavy as hydrogen.

3. Oxygen is a supporter of combustion and animal life; but hydrogen is a combustible gas and does not support animal life.

4. Hydrogen is less soluble in water than oxygen.

68. **Ozone** (O_3).—Oxygen sometimes appears in a modified form called ozone. When an electric machine is at work, or when an object is struck by lightning, the smell of ozone can be noticed in the vicinity.

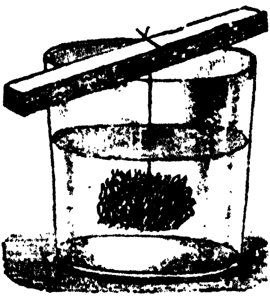

Fig. 16.

Ozone has a strong and rather unpleasant smell. It is more active than oxygen. Most metals—even mercury—are at once acted upon by it. It bleaches vegetable colours, and rapidly destroys organic matter. It contains in its molecule three atoms of oxygen, while oxygen contains only two.

69. **Metals may be recovered from their salts**; or **earthy substances contain metals**.

Expt. 60.—Dip the clean blade of a knife in a solution of copper sulphate. The blue liquid loses its colour and the blade gets coated with a reddish brown powder of metallic copper, where it dipped in the liquid. Here, the iron displaces the copper, atom for atom, forming ferrous sulphate.

Bluestone.		Iron.		Iron sulphate.		Copper.
$CuSO_4$	+	Fe	=	$FeSO_4$	+	Cu.

Expt. 61.—Take a solution of lead acetate, commonly called sugar of lead. Allow a bit of zinc to hang in the liquid

for some hours. An exchange will take place between the two metals, zinc dissolving in the acid to form zinc acetate and an equivalent weight of lead being set free in bright crystals. This will be deposited on the remaining zinc, forming a tree-like growth called the lead-tree or the tree of Saturn. (Fig. 16.)

Expt. 62.—Take some solution of silver nitrate in water. Add a few drops of mercury to it. A silver tree will grow round the metal in a few days.

Questions.

* 1. Describe two different methods for preparing oxygen. To which would you assign the preference for (*a*) cheapness, (*b*) rapidity with which the gas is evolved, and (*c*) purity of the gas obtained?

* 2. Mention the chief properties of oxygen. How is it collected? What is its test?

3. Explain the uses of oxygen dissolved in water.

4. Describe experiments to prove that

   (*a*) Substances become heavier by oxidation.

   (*b*) Substances which do not burn in air burn in oxygen.

* 5. Describe what takes place, when (*a*) red oxide of mercury is heated in air, (*b*) a burning candle is brought into a jar of oxygen, (*c*) chlorate of potash is heated.

* 6. If a watch-spring were burnt in a closed vessel of oxygen, would the weight of the vessel and its contents be altered by the combustion? Give reasons for your answer.

Ans. The weight of the vessel after combustion will be the same as before. All that has taken place is chemical combination between the watch spring and the oxygen inside the closed vessel to form oxide of iron, which also remains within the vessel. Since no new substance has come into the vessel, nothing has gone out of it, and the weight of a compound is exactly equal to the sum of the weights of the constituents, the vessel weighs neither more nor less.

7. Why do substances not burn as actively in the air as they do in oxygen?

Ans. (*a*) In air, every molecule of oxygen is surrounded by four molecules of inert nitrogen; so less surface is exposed to the action of oxygen. (*b*) Part of the heat of the burning material is spent in raising the temperature of the nitrogen molecules.

8. Calculate the weight of the substances formed, when 100 oz. of potassium chlorate is heated in air.

9. In what other form does oxygen exist? How does this form differ from oxygen?

*** 10. State how the following substances are prepared and mention some of the properties of each: Mercuric oxide, lime-water, quick-lime, slaked-lime and caustic soda.**

*** 11. What takes place when (*a*) a piece of zinc is placed in a solution of lead acetate, (*b*) a piece of iron is dipped in a solution of bluestone.**

*** 12. A piece of iron when placed in a solution containing copper sulphate precipitates copper. Name the new compound which is formed during the inter-action. Assuming that 20 grammes of copper have been precipitated, calculate the weight of (*a*) the copper sulphate which has been decomposed and of (*b*) the new compound which has been formed.**

*** 13. Iron precipitates copper from solutions containing the latter metal. What compound is formed when a plate of iron is placed in a solution of copper sulphate? Write an equation for the change which takes place, and calculate the quantity of the compound referred to which can be obtained from 1 lb. of the copper salt. Fe = 56; Cu = 63·5; S = 32; O = 16.**

CHAPTER IX.

CARBONIC ACID GAS (CO_2.)

70. **Occurrence.**—Carbonic acid gas is also called carbon dioxide and sometimes carbonic anhydride. Miners call it choke-damp or after-damp. It occurs free in air. It is also found in the water of many springs, at the bottom of old wells and coal mines, and is evolved from volcanoes. It occurs combined in chalk, lime-stone and sea-shells. It is always produced when organic substances decay, and when substances containing carbon burn.

71. Preparation of Carbonic acid gas.—*Expt.* 68.—Take a few pieces of chalk, lime-stone or marble. Put them into a flask fitted with a cork, bent tube and tube-funnel. Pour some dilute hydrochloric acid down the funnel. The chalk dissolves in the acid forming calcium chloride and water; while carbonic

acid gas escapes in bubbles and is collected by downward displacement.

Chalk.		Hydrochloric acid.		Carbonic acid gas.		Water.		Calcium chloride.
$CaCO_3$	+	$2HCl$	=	CO_2	+	H_2O	+	$CaCl_2$

All carbonates, when treated with dilute hydrochloric **acid or sulphuric** acid, liberate Carbon dioxide. Many, such as limestone, liberate it when heated.

Potashes.		Hydrochloric acid.		Potassium chloride.		Carbon dioxide.		Water.
K_2CO_3	+	$2HCl$	=	$2KCl$	+	CO_2	+	H_2O
$CaCO_3$	+	H_2SO_4	=	$CaSO_4$	+	CO_2	+	H_2O

Limestone.				Lime.		Carbon dioxide.
$CaCO_2$	+	heat	=	CaO	+	CO_2

Note.—*Lime is different from limestone* (1) If we pour acid upon lime, bubbles are not given off; it has therefore no carbonic acid gas. (2) If we pour water on it, we notice the solid substance falls to powder and becomes hot enough to make the water boil.

Lime.		Water.		Slaked lime.
CaO	+	H_2O	=	$Ca(OH)_2$.

72. **Properties.**—(1) Carbon di-oxide is a colourless gas, having a feeble acid taste and a faint smell.

(2) It is $1\frac{1}{2}$ times as heavy as air; hence it is prepared by downward displacement, and can be poured from one vessel to another like water.

Expt. 64.—Take a jar of carbon di-oxide and pour it down over a burning candle. The candle is extinguished as the gas falls upon the flame.

Expt. 65.—Balance an open glass vessel on a pair of scales, and then pour into the glass carbonic acid gas. The weight increases as the air is displaced by the carbonic acid, thus showing that carbon di-oxide is denser than air.

Note.—A gas is collected by downward displacement (Fig. 23), when it is considerably heavier than air. The end of the tube con-

ducting the gas is brought into a bottle, placed *mouth* upwards. The issuing gas, being heavier, falls down to the bottom of the vessel and fills it, displacing the air.

(3) It is moderately soluble in water, and is readily absorbed by caustic soda and caustic potash.

(4) It is not a combustible gas, nor a supporter of combustion or animal life.

Note.—Carbon di-oxide does not burn, because it already holds in combination all the oxygen it has the power to combine with. Before it can burn again, it must be decomposed.

(5) It puts out a burning taper, and turns limewater milky. (*This is the* **test for carbonic acid gas.**)

(6) It is decomposed by red-hot potassium or burning magnesium which unites with the oxygen and sets free carbon as soot.

$$2\,Mg \quad + \quad CO_2 \quad = \quad 2\,MgO \quad + \quad C.$$

73. **Carbonic acid.**—A solution of carbon dioxide in water is feebly acid, turning blue litmus to a port-wine red colour, while the stronger acids turn it scarlet red. This solution may be regarded as the true carbonic acid.

Carbonic anhydride.		Water.		Carbonic acid.
CO_2	$+$	H_2O	$=$	H_2CO_3

The solution (H_2CO_3) acts upon basic solutions and forms salts called *carbonates*.

Carbon dioxide in solution.		Caustic potash.		Soluble potashes.		Water.
$\overbrace{CO_2 + H_2O}$	$+$	$2KOH$	$=$	K_2CO_3	$+$	$3H_2O$

Carbonic acid.		Slaked lime.		Insoluble chalk.		Water.
$\overbrace{CO_2 + H_2O}$	$+$	$Ca(OH)_2$	$=$	$CaCO_3$	$+$	$2H_2O$

The acid† (H_2CO_3) is so unstable that it breaks up into carbon dioxide and water.

74. **Composition of carbon dioxide.**—When carbon is burnt in oxygen, no change of volume occurs, and carbon dioxide is therefore said to contain its own volume of oxygen. Again, if a known weight of pure carbon such as graphite or diamond be burnt in oxygen, and the carbon dioxide formed be weighed, it will be found that 12 parts by weight of carbon unite with 32 parts by weight of oxygen to form 44 parts by weight of carbon dioxide (CO_2).

75. **Carbon mon-oxide** (CO), or *carbonic oxide*.

(i) *Preparation.*—When carbon di-oxide is passed over red-hot charcoal, iron, or zinc, carbonic oxide is formed.

$$\underset{\text{Carbon di-oxide.}}{CO_2} + \underset{\text{Charcoal.}}{C} = \underset{\text{Carbonic oxide.}}{2\,CO.}$$

$$\underset{\text{Iron.}}{Fe} + \underset{\text{Carbon di-oxide.}}{CO_2} = \underset{\text{Iron oxide.}}{Fe\,O} + \underset{\text{Carbonic oxide.}}{CO.}$$

Note.—If steam be passed over over red-hot charcoal, carbon monoxide and hydrogen will be formed.

$$H_2O + C = CO + H_2$$

(ii) *Properties.*—(1) Carbon monoxide is a colourless, tasteless gas, having a faint disagreeable smell. It is very poisonous, when breathed.

(2) It is almost insoluble in water.

(3) It does not support combustion, but burns in air with a pale blue flame.

(4) At high temperatures, carbon mon-oxide has a very strong attraction for oxygen, and is hence a good reducing agent.

$$CuO + CO = Cu + CO_2$$

† For the explanation of the terms acid, base, &c., *vide* Chap. xiii.

Note.—A **reducing agent** is a substance which, combining with the non-metal of a mineral, leaves the metal in the pure state. For example, when hydrogen is passed over heated copper oxide or iron rust (FeO), it combines with the oxygen to form water and leaves the copper or the iron in the metallic state.

Questions.

* 1. How is carbonic acid gas prepared? Give its chief properties.

* 2. How would you use a chemical equation to ascertain the weight of chalk required to produce 100 lbs. of calcium chloride?

* 3. What gas is formed when hydrochloric acid acts upon chalk or marble? How much of this gas by weight can be obtained from 100 lbs. of either of these materials?

4. How is carbonic oxide prepared? By what other name is it called? Give its chemical formula and chief properties.

* 5. What weight of carbonic acid gas is obtained by burning 50 grs. of carbon and what weight of oxygen by heating the same quantity of mercuric oxide?

* 6. What do you *see* when hydrochloric acid is poured on to chalk? Represent the chemical change by an equation.

7. Distinguish between "collecting a gas by upward displacement" and "collecting it by downward displacement." Give two diagrams illustrating your answer. (See Figs. 21, 23).

8. How would you easily distinguish between lime-water and a solution of caustic potash?

Ans. (*a*) The former is slightly alkaline; but the latter strongly. (*b*) If carbon dioxide is passed into the former, a white precipitate is formed; if into the latter no precipitate.

* 9. How is lime obtained from chalk? By what tests can lime be distinguished from chalk?

10. Why does carbon di-oxide not burn? How would you ascertain its composition?

CHAPTER X.

COAL AND COAL-GAS.

76. **Coal is a natural variety of carbon less pure than wood charcoal. It consists of the remains of plants and trees which once flourished on the earth's surface but which have become altered, having been buried under the earth for ages.**

Proof of the vegetable origin of coal.—(1) If we go down a coal pit, we shall see the roof and floor of the passages covered with impressions of leaves and other parts of plants. (2) If we slice a piece of coal very thin, we see in the coal itself marks which show that it once was all vegetable matter.

Composition of Coal.—The chief constituent is carbon; but it also contains a small quantity of hydrogen, oxygen and nitrogen. Besides these, there are certain mineral impurities of which iron pyrites (FeS_2) and potassium carbonate (K_2CO_3) are the chief.

Coal contains carbon.—*Expt.* 66.—Burn a piece of coal in a open vessel and pour a little lime-water in it. The lime-water at once turns milky, showing the formation of carbonic acid gas which is composed of oxygen and carbon.

77. **Varieties of Coal.**—(1) Peat, (2) Lignite, (3) Anthracite, and (4) Bituminous coal Of these the last two are the most important.

Anthracite coal is very hard. It is of an iron black colour with a semi-metallic lustre. It takes fire with great difficulty, and burns with very little flame giving off no smoke. It contains upwards of 90 per cent. of carbon but little volatile matter. This kind is much used in steam engines and for melting purposes, where great heat is required.

Bituminous coal is very soft. It contains about 79 per cent. of carbon. This is never burnt completely even in the open fire. It is much used in the preparation of coal gas.

78. **Burning coal in open air.**—If coal is burnt in *open* air, its constituents mostly combine with the oxygen of the air; the carbon is converted into carbon di-oxide and very often into carbon mon-oxide which imparts a smell and a blue colour to the flame, the hydrogen burns into water, the nitrogen escapes chiefly as a gas, and some incombustible and non-volatile ash remains. This ash is composed of the saline and earthy residue such as potash, silica, potassium chloride, magnesia, iron oxide, &c.

79. Burning coal in closed vessels.†—When coal is heated to a high temperature in closed vessels provided with a delivery tube, its constituents, chemically acting upon one another, form Coal-gas, tar, ammonia, water, hydrogen sulphide, carbon di-sulphide and some other volatile bodies; while a residue of grey impure carbon called coke is left behind in the vessel.

80. Preparation of coal gas.

Expt. 67.—Put some coal-powder into the bowl of a common long tobacco pipe and cover the top with moist clay. After the clay is well dried, heat the bowl of the pipe over the flame of a spirit lamp. In a short time, a yellow smoke consisting of a

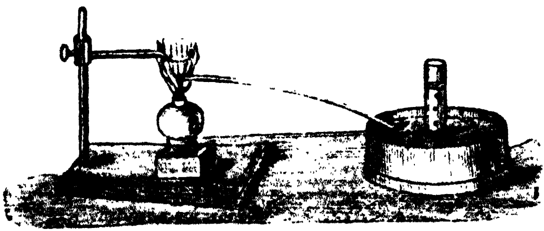

Fig. 17.

mixture of various vapours will come out at the end of the pipe. This smoke will burn with a bright flame when lighted. But the flame will be unsteady. If the end of the pipe is pushed under water and the gas is collected in bottles under water, most of the impurities will dissolve in the water, and coal gas is obtained nearly pure.

In gas-works the coal is heated in large iron retorts and the gas is collected in enormous gas holders made of iron-plate.

† The process of heating substances in closed vessels and collecting the products formed is called destructive *distillation*.

Note.—*The impurities are:*—

1. Carbon di-oxide.
2. Hydrogen sulphide.
3. Carbon di-sulphide.
4. Ammonia.
5. Coal-tar.
6. Vapour of water.

The tar contains a great variety of substances, from some of which the well-known aniline colours, mauve and magenta are prepared.

81. **The chief constituents of coal gas** are:—

(*a*) *Illuminating gases:*

(1) Ethylene (C_2H_4).
(2) Acetylene (C_2H_2).
(3) Benzene (C_6H_6).

These hydro-carbons impart brightness to the flame.

(*b*) *Heat producing gases:*

(1) Hydrogen.
(2) Carbon mon-oxide.
(3) Marsh gas.

These burn with a non-luminous flame but produce much heat.

Thus, we see that coal gas is a mixture of several gases some of which are useful for illuminating, whilst others for heating purposes.

82. **Properties of coal gas.**—1. Coal gas, when pure, is an invisible and colourless gas with a faint smell.

2. It is practically insoluble in water.

3. It is 8 times lighter than air. Hence it is used for filling balloons.

4. It is highly inflammable, and does not support combustion. When it burns, carbonic acid gas and water are formed.

Because of its inflammability, coal gas is now commonly used in towns for lighting purposes.

83. **Coal gas contains carbon and hydrogen.**

Expt. 68.—(*a*) **Hold a piece of paper over burning coal gas so as not to be burned; it will be seen covered with a black layer of soot or carbon. (*b*) When coal gas is burnt in air, carbonic acid gas is formed. This may be proved by passing the products of combustion through lime-water which will become milky.**

Expt. 69.—When a dry, bright, cold vessel is held over the flame of coal gas, water is deposited on the inside. Hydrogen must therefore be present in coal gas.

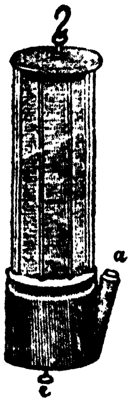

Fig. 18.

84. **Explosions in coal pits.**—*How produced and prevented.*

Marsh gas (CH_4), called by miners fire-damp, issues in large quantities from the crevices of coal-pits. This combustible gas, when mixed with ten times its volume of air or twice its volume of oxygen, forms an explosive mixture which takes fire at the miner's candle and a dreadful explosion occurs, causing the death of the miners.

The carbon and the hydrogen of the gas combine with the oxygen of the air and form carbonic acid gas and steam, while the nitrogen remains uncombined. These gases cannot support human life so that the miners die as surely as they do from the direct effects of the flame.†

Marsh gas. Oxygen.

$$CH_4 + 2O_2 = CO + 2H_2O$$

These explosions are prevented by the use of **Davy's Safety-lamp.** This is merely an ordinary oil-lamp enclosed within a cylinder of fine wire-gauze. **(Fig. 18.)**

† **The air left in the mine after an explosion is called "*after damp*" or "*choke damp*"; for persons entering a coal mine after an explosion are suffocated.**

Principle.—(1) **A mixture of fire-damp and air takes fire only at a very high temperature so that a substance igniting it must be not merely red-hot, but white-hot. In short, a mixture of fire damp and air explodes only by contact with flame. (2) The metallic wire-gauze has the property of conducting away heat so rapidly that the flame does not pass outside the gauze so as to raise the explosive mixture to the point of ignition.**

Action.—When a lamp of this kind is taken into an atmosphere in which an explosive mixture of marsh gas and air is present, this mixture coming into the wire-gauze through the meshes makes the lamp burn with a pale enlarged flame; and a small explosion also occurs inside the gauze, but the flame inside cannot pass through. Hence no serious explosion takes place. The flickering of the flame and the occurrence of small explosions inside the gauze warn the miners to withdraw.

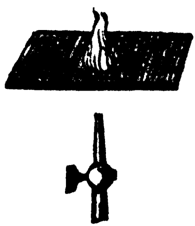

Fig. 19.

85. **Wire-gauze conducts away heat rapidly.**

Expt. 70.—Hold a piece of wire-gauze close over a jet of hydrogen or coal gas.* Now light the gas on the top of the gauze. The gas does not burn below, even when the gauze is removed several inches above the jet. (Fig. 19)

Expt. 71.—If we bring the wire-gauze over the flame of hydrogen or coal gas, the flame is flattened and does not pass above the gauze.

Expt. 72.—Pour a stream of burning alcohol on a piece of wire-gauze. The liquid which passes through does not burn.

The metallic wire-gauze conducts away heat rapidly. So, when the burning alcohol is passed through the meshes of the gauze, the liquid that passes through is cooled down below the temperature requisite for burning.

86. **Marsh gas.** (CH_4).

This gas is so called because it occurs naturally in stagnant water or in marshes. It is formed by the decomposition of organic matter out of contact with air. It is also the gas produced in coal mines and called by the miners fire-damp. It is one of the chief constituents of coal gas.

Properties.—(1) Marsh gas is a colourless gas without taste or smell.

(2) It is slightly soluble in water.

(3) It does not support combustion but burns with a bluish flame.

(4) A mixture of marsh gas and air explodes in contact with flame, water and carbon di-oxide being formed.

Questions.

1. What is coal? How would you show that it is of vegetable origin? Mention some of its uses.

* 2. Coal, it is said, contains carbon and hydrogen. How could you prove the presence of both these elements in coal?

3. What are the different varieties of coal? Why do some kinds of coal yield more gas than other kinds?

Ans. Some kinds (anthracite) contain more carbon and less hydrogen than others, and therefore give less gas and more coke.

* 4. When a piece of coal is burnt in air, it disappears leaving behind a little ash. What is the composition of this ash and why does it not also disappear? Which constituents of the coal have disappeared and how could you prove that they have not been destroyed but only changed in form?

* 5. What is given off and what is left behind when coal is (1) completely burnt in an open grate, and (2) heated strongly in a closed vessel provided with a delivery tube?

* 6. How is coal gas prepared? Mention some of its chief properties.

* 7. Describe how you would prove that (*a*) coal gas is lighter than air, and that (*b*) it contains carbon and hydrogen.

* 8. Is coal gas an element, a compound or a mechanical mixture? Give the reason for your answer.

9. What is left behind in the distillation of coal? What besides gas is given off in the process? What are the chief uses of coal gas?

* 10. What is fire-damp and how are explosions in coal mines produced by it? Explain the action of Davy's safety lamp in preventing explosions. Persons who go down a coal mine immediately

after an explosion are frequently suffocated. How do you account for this?

* 11. When a stream of burning alcohol is poured on a piece of wire-gauze, the liquid which passes through does not burn. Give an explanation of this phenomenon and mention a useful application of the principle it illustrates.

* 12. (*a*) Explain the *principle* of the Davy's safety-lamp, and (*b*) draw a picture of it.

13. 40 grams of marsh gas are to be completely burnt. Calculate the weight of air required for the combustion; also the products thus obtained.

CHAPTER XI.

FLAME.

87. **A Flame** *consists of combustible gases raised to incandescence by means of chemical action.* Hence in any case before flame can be produced, (1) the combustible body should be converted into vapour, if it is not already in the state of vapour; (2) the vapour must be brought into an atmosphere with which it can re-act chemically; (3) the temperature must first reach a certain limit known as the point of ignition.

Note.—The temperature of ignition varies with different bodies. Some like phosphorus take fire at a low temperature, while others like magnesium or fire-damp do so at a high temperature. A flame is extinguished, if its temperature is by any means reduced below the point of ignition of the vapours consumed in it.

88. **The Luminosity of the flame.**—(i) The light-giving property of a flame is not due to the operation of any one simple cause. There are three causes which may operate, either separately or together. These are:—

(1) *The presence of fine particles of incandescent solid matter in it.* The flame of oil or that of coal gas is very luminous, because minute particles of solid carbon are present in it. The flame of hydrogen is non-luminous, because there is no solid matter present in it. The flame,

however, becomes bright, if powdered charcoal or any dust is introduced into it. This is clearly seen in the lime-light with the oxy-hydrogen flame.

(2) *The density of the flame-gases.* The denser a gas is the more light it gives. Thus, a candle at the top of a high mountain as Mont Blanc gives less light than the same candle at the sea level, though the rate of combustion is the same.

(3) *The increase of temperature* of the flame-gases. When phosphorus is introduced into chlorine, it spontaneously inflames and burns with a pale greenish flame. If, however, the chlorine be previously heated by being passed through a red hot tube and the phosphorus be boiling, the combustion is accompanied by a flame of very considerable luminosity.

(ii) **The heat of the flame** depends upon the energy and rapidity with which chemical action takes place in it. This is why the flame of hydrogen is hotter than that of coal gas.

89. **Bunsen's gas burner.**—(Fig. 28, Chem. Pr., p. 70). This is a gas lamp used to burn coal gas completely at once so that it may give out no smoke, but as much heat as possible.

This burner consists of a vertical tube of metal screwed to a hollow support. The gas is admitted by a horizontal tube also screwed to the support. At the junction, there are several holes for the admission of air. The gas passes up the tube drawing the air through the holes near the bottom, and burns with a hot but non-luminous and perfectly smokeless flame, when kindled at the top.

If the holes be stopped, the flame becomes bright and smoky; for, the supply of air and consequently of oxygen becomes diminished, and the solid particles of carbon are not completely oxidized. Thus, it can be also used to illustrate the principle of luminous and non-luminous flames.

90. The principal parts of a candle flame.

1. *A black cone in the inside consisting of heated unburnt gas given off by the wick*; or an area of no combustion.

Fig. 20.

Here, the heat of the flame causes the solid matter of the candle to melt; the liquid, ascending through the wick, is decomposed into combustible gases such as marsh gas and ethylene which constitute the dark part of the flame. These hydro-carbons are unburnt for want of oxygen.

Note.—The existence of unburnt gases in the dark cone may be easily shown by the following experiments.

Expt. 73.—Take a small bent glass tube and bring one end of it into the dark cone of the flame; presently yellowish brown vapours will be seen to pass down the tube and issue at the other end. These vapours will be found inflammable and may be lighted.

Expt. 74.—Lower a piece of wire gauze into the flame of a candle so that it is in contact with the dark inner cone. Yellowish vapours will pass above the gauze. Light the vapours. They will burn, shewing that the inner dark cone consists of unburnt gases.

2. *An inner bright or luminous zone where carbon is separated out, light is given off and the combustion is incomplete*; or an area of incomplete combustion.

In this part of the flame, the supply of oxygen being insufficient, the hydro-carbon gases formed in the dark zone are not all burnt, but are converted into carbon mon-oxide and water, together with small quantities of carbon dioxide and hydrogen; while part of the carbon is set free in the form of soot. It is these solid particles of carbon heated to incandescence that make this part of the flame luminous.

Note.—This zone is called the *reducing flame;* for, if an oxide of a metal, for example, litharge (PbO) or tin-stone (SnO_2), is heated in it, the carbon present in the flame takes up the oxygen and leaves the metal pure.

3. ***A blue scarcely visible outer zone or region where the combustion is complete and the temperature is highest;*** or an area of complete combustion.

This zone being in contact with air, the white hot particles of carbon, the hydrogen which escapes combustion in the luminous zone, and the carbon mon-oxide burn away at once into water and carbonic acid gas. Since the solid particles of carbon are mostly burnt away and the flame-gases are cooled down by the admixture of air, this portion of the flame is non-luminous.

The formation of carbon-dioxide and water can be shewn by the lime-water and the cold glass tumbler experiments; *vide* experiments 18, 19. The pale blue portion of the flame is due to the combustion of hydrogen.

Note.—As metals, when heated in this zone, take up oxygen and are converted into oxides, this is called the *oxidizing flame.*

N.B.—Besides these three zones, a small bright blue region may be noticed at the base of the flame.

Questions.

* 1. Why does a candle flame give off so much light, while the flame of hydrogen gives so little?

* 2. Explain why hydrogen gives very little, and coal gas a great deal of light, when burnt in the air. Describe an arrangement by which the luminosity of the flame of coal gas may be diminished. How can the flame of hydrogen be made brighter?

* 3. Of how many different parts does the flame of an ordinary candle consist? Mention the substances found and the changes taking place in each.

* 4. Explain with the help of a diagram the nature of a candle flame.

5. Describe an experiment to show that the substance of a taper is turned into vapour before it begins to burn.

6. Upon what does the luminosity of a flame depend, and on what its heat?

7. If a current of air is blown into the flame of an ordinary candle, the flame becomes less bright. Why is this?

8. What part of the candle flame is called the reducing flame, and what the oxidizing flame? Why?

9. Sketch and describe Bunsen's gas burner and show how it illustrates the *principle* of luminous and non-luminous flames.

10. If a piece of cold copper is placed on to a flame, the flame does not touch it. Why?

CHAPTER XII.

NITROGEN: *Symb. N.; At. Wt. 14.*

91. **Occurrence.**—In the *free* state, nitrogen is present in the atmosphere, of which it forms about four-fifths by volume. *In combination*, nitrogen is found in ammonia, nitre, in the flesh of animals, in plants and in some food-stuffs.

92. **Preparation.**—(i) Nitrogen is chiefly prepared by removing oxygen from the air. This is commonly done by burning a piece of phosphorus in air, confined over water. The phosphorus, in burning, combines with the oxygen forming dense white fumes of phosphoric anhydride. These gradually dissolve in the water and nitrogen remains.

(ii) Nitrogen in a pure state is prepared from the atmosphere by passing over red-hot metallic copper a stream of air, freed from carbon di-oxide and water-vapour. The air, on passing over the heated copper, is deprived of the whole of its oxygen, cupric oxide being formed; while the nitrogen passes on and may be collected over water in the pneumatic trough.

93. **Properties.**—1. Nitrogen is a colourless gas without taste or smell.

2. It is very slightly soluble in vater.

3. It is slightly lighter than air, its Sp. Gr. being 0·97.

4. It does not burn; nor does it support combustion.

5. It is one of the most chemically inert substances known, combining directly with only a very few elements and that with difficulty.

Test for Nitrogen.—*Nitrogen puts out a burning taper, but does not turn lime-water milky.*

Compounds of Nitrogen.

94. **Ammonia** (NH_3). Ammonia is also called *spirits of hartshorn;* for, it was formerly prepared by distilling horns, feathers and ivory. It is present in the air, being derived from putrefying animal matter.

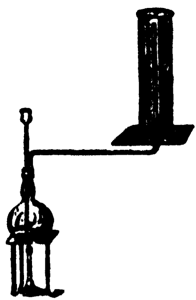

Fig. 21.—Preparation of a gas by upward displacement of air.

(i) *Preparation.*

Equal parts of slaked lime and sal-ammonic (NH_4Cl) are mixed with water so as to make a thick paste. When the mixture is gently heated in a flask, the gas is given off rapidly and may be collected in dry bottles by upward (Fig. 21) displacement or over mercury; while calcium chloride and water are left in the flask.

Sal-ammoniac.		Slaked lime.		Ammonia.		Calcium chloride.		Water.
$2NH_4Cl$	+	$Ca(OH)_2$	=	$2NH_3$	+	$CaCl_2$	+	$2H_2O$.

Note 1.—Ammonia is now usually obtained from the waste liquors collected during the destructive distillation of coal in the manufacture of coal-gas.

Note 2.—A gas is collected by upward displacement, when it is considerably lighter than air. The end of the tube conducting the gas is brought into a bottle held *mouth downwards.* The issuing gas, being lighter, ascends displacing the air and fills the bottle.

(ii) *Properties.*—1. Ammonia is a colourless, trans-

parent gas, having a powerfully pungent smell and a strong caustic taste.

2. It is a strong stimulant to the nerves, bringing tears to the eyes.

3. It is lighter than air, its Sp. Gr. being 0·59.

4. It is extremely soluble in water, one volume of water at the ordinary temperature dissolving about 800 volumes of the gas.

5. It is not a supporter of combustion and does not burn in the air, but burns in oxygen or heated air with a greenish yellow flame.

6. It is highly alkaline.

7. It combines directly with acids, forming salts known as ammonium salts.

Test for Ammonia.—Ammonia may be recognised by its smell, alkaline reaction, and by giving dense white fumes of ammonium chloride when brought in contact with fuming hydrochloric acid.

Uses.—Ammonia is used (1) as a chemical re-agent, and (2) in the liquid form, largely in the manufacture of ice.

95. **Nitric acid.** (HNO_3). Nitric acid is formed in the atmosphere in very small quantities by the flash of lightning through moist air.

(i) *Preparation.*—Nitric acid is prepared by heating a mixture of about equal quantities of nitre (KNO_3) and strong sulphuric acid in a retort; when, the nitric acid distils over and is condensed in a flask kept cool in a basin of water. (Fig. 22.)

Nitre.	Sulphuric acid.	Nitric acid.	Potassic hydrogen sulphate.

$$KNO_3 + H_2SO_4 = HNO_3 + KHSO_4$$

Note.—When strongly heated, the following reaction takes place:

$$2\,KNO_3 + H_2SO_4 = 2\,HNO_3 + K_2SO_4$$

Thus, for the same quantity of sulphuric acid we get twice as much nitric acid.

The acid which is collected is of a yellowish colour owing to the partial decomposition of the acid into nitric per-oxide.

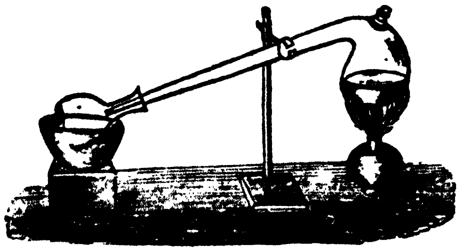

Fig. 22.

Nitric acid is an article of commercial manufacture. In this process, potassium nitrate is replaced by sodium nitrate ($Na\ NO_3$), as being the cheaper material.

The reaction in this case is represented thus:

Chili-saltpetre.	Sulphuric acid.	Nitric acid.	Sodic hydrogen sulphate.

$$Na\ NO_3 + H_2\ SO_4 = HNO_3 + Na\ HSO_4$$

(ii) *Properties.*—1. Nitric acid, when pure, is a colourless liquid, having a Sp. Gr. of 1·53, and gives off colourless fumes when exposed to the air.

2. When heated or exposed to the sun, it undergoes decomposition into oxygen and nitrogen oxides, one of which nitric per-oxide (NO_2) is coloured.

3. It is intensely corrosive. When strong, it causes painful wounds in contact with the skin; while in more dilute conditions, it stains the skin and other organic materials bright yellow.

4. It is one of the most active chemical substances, dissolving all the metals except gold and platinum, and acts violently on animal and vegetable matter decomposing them.

5. It is a powerful oxidizing agent, giving up its oxygen with ease. Many substances burn up in strong nitric acid. Turpentine, when mixed with it, inflames.

Expt. 75.—Plunge the end of a piece of red-hot charcoal into strong fuming nitric acid contained in a wide test-tube. The charcoal bursts into flame, combining with oxygen of the acid to form carbon dioxide.

Note 1.—When an acid acts upon a metal, the hydrogen of the acid is generally liberated and the metal takes its place. When nitric acid acts upon a metal, the hydrogen evolved combines with a part of the oxygen of the acid to form water and reddish brown fumes of nitrogen peroxide are given off.

Note 2.—**An oxidizing agent** is a substance which readily transfers its oxygen to other substances.

Tests for nitric acid.—*Expt.* 76.—Add copper turnings to some nitric acid; on warming, red fumes will be given off.

Expt. 77.—Add a few drops of nitric acid to a little water contained in a test-tube, and then add *some strong* sulphuric acid, and shake until the liquids are thoroughly mixed. Allow this mixture to cool *completely*, and then pour gently on to the surface of the liquid a strong *cold* solution of ferrous sulphate. A black ring will form where the two liquids meet.

(iii) *Uses.*—Nitric acid is used (1) in the manufacture of sulphuric acid, (2) in the preparation of nitrates from metals, (3) in the Grove's battery to prevent polarization, and (4) to engrave upon copper.

96. Oxides of nitrogen.

There are five oxides of nitrogen, *viz.*, nitrogen monoxide or nitrous oxide N_2O; Nitrogen dioxide or nitric oxide (N_2O_2 or) NO; Nitrogen trioxide N_2O_3; Nitrogen tetroxide or nitric peroxide (N_2O_4 or) NO_2; Nitrogen pentoxide N_2O_5.

97. Nitrous Oxide (N_2O).

(i) It is *prepared* by heating ammonium nitrate (NH_4NO_3) in a flask and is best collected over warm water.

(ii) *Properties.*—1. It is a colourless gas, having a faint smell and a peculiar sweetish taste.

2. When breathed in, it produces a peculiar intoxicating effect which shows itself in the form of hysterical laughing. Hence it is commonly called *laughing gas*.

3. It is somewhat soluble in cold water, and is heavier than air, its Sp. Gr. being 1·5.

4. It supports combustion almost as well as pure oxygen. Thus, a red hot splinter of wood is instantly rekindled, when plunged into the gas.

Note.—Nitrous oxide is distinguished from oxygen by the fact that, when added to nitric oxide, it does not produce reddish brown vapours; whereas, when oxygen is mixed with nitric oxide, coloured gases are instantly formed.

98. **Nitrogen di-oxide** (N_2O_2 or) NO.

This is formed when nitric acid acts upon some metals as copper.

Nitric acid. Copper. Copper nitrate. Water. Nitric oxide.

$$8\,HNO_3 + 3\,Cu = 3\,Cu\,(NO_3)_2 + 4\,H_2O + 2\,NO.$$

Properties.—It is a colourless transparent gas, very sparingly soluble in water. When brought in contact with air, it is oxidised into reddish brown fumes of nitric peroxide.

Questions.

1. Explain how nitrogen is obtained from the air by the use of copper turnings. Mention its chief properties.

2. The compounds of nitrogen are not prepared from the nitrogen present in air. Why is this?

3. How is ammonia prepared? How much ammonia can be obtained from 50 grammes of ammonium chloride?

*4. How is nitric acid prepared? What are its properties? Calculate the weight of the re-acting substances we should take, in order to get 20 grammes of nitric acid from nitre?

*5. Complete the following equations and explain fully their meaning:

$$KNO_3 + H_2SO_4 =$$

$$Na\,NO_3 + H_2SO_4 =$$

Supposing the compounds represented by the formulæ KNO_3 and $Na\,NO_3$ were of the same price, which would be the more economical compound to use in the manufacture of nitric acid? Give the reasons for your answer.

Answer.

$$\begin{array}{ccccccc} KNO_3 & + & H_2SO_4 & = & KHSO_4 & + & HNO_3 \\ \underbrace{39+14+48}_{101} & + & \underbrace{2+32+64}_{98} & = & \underbrace{39+1+32+64}_{136} & + & \underbrace{1+14+48}_{63} \end{array}$$

$$\begin{array}{ccccccc} Na\,NO_3 & + & H_2SO_4 & = & HNO_3 & + & Na\,HSO_4 \\ \underbrace{23+14+48}_{85} & + & \underbrace{2+32+64}_{98} & = & \underbrace{1+14+48}_{63} & + & \underbrace{23+1+32+64}_{120} \end{array}$$

From the above equations, it is clear that we would use 101 and 85 parts by weight of potassium nitrate and sodium nitrate respectively in order to get 63 parts by weight of nitric acid. Therefore it would be more economical to use $NaNO_3$; for by spending 85 grs. of it, we can get as much of nitric acid (63 grs.) as by using 101 grs. of KNO_3.

6. How is nitrogen dioxide prepared? What takes place when it is brought in contact with the air?

7. Which is called the laughing gas? Why is it so called? How is it prepared, collected and distinguished from oxygen?

8. What takes place when

*(1) Saltpetre and sulphuric acid are mixed together and heated.

(2) Red-hot carbon is plunged into concentrated nitric acid.

(3) Nitric acid is poured upon copper turnings

(4) Sal-ammoniac is mixed with slaked lime?

9. Name the five oxides of nitrogen with which you are acquainted and give their composition by weight.

CHAPTER XIII.

CLASSIFICATION OF COMPOUNDS.

99. **Oxides, Anhydrides** and **bases.**

An *oxide* is a compound resulting from the combination of oxygen with any other element; as, red oxide of mercury (HgO); magnetic oxide of iron (Fe_3O_4); carbon dioxide (CO_2); sulphur dioxide (SO_2); water (H_2O).

An *anhydride* is an oxide of a non-metal which, when treated with water, furnishes an acid: as, phosphoric anhydride (P_2O_5), carbonic anhydride (CO_2).

$$P_2O_5 + 3H_2O = 2H_3PO_4$$
$$N_2O_5 + H_2O = 2\,HNO_3$$
$$SO_3 + H_2O = H_2SO_4$$
$$CO_2 + H_2O = H_2CO_3$$

A *base* is an oxide of a metal which has the power of combining with an acid to form a salt; as, cupric oxide (CuO), red oxide of mercury (HgO); quick-lime (CaO).

$$CuO + H_2SO_4 = CuSO_4 + H_2O$$
$$CaO + H_2CO_3 = CaCO_3 + H_2O.$$

100. **Hydroxides and Alkalis.**—*Hydroxides* or hydrates are compounds resulting from the direct or indirect combination of metallic oxides with water; as, caustic soda (NaOH); slaked lime Ca $(OH)_2$. Hydroxides are also sometimes called bases.

$$CaO + H_2O = Ca\,(OH)_2$$
$$Na_2O + H_2O = 2\,NaOH.$$

Alkalis are the soluble bases of the metals sodium, potassium, &c. as, KOH; NaOH. They turn red litmus solution blue, have the power of neutralizing acids, and produce a soapy feeling when rubbed between the fingers.

Test for Alkalis.—*Alkalis turn red litmus paper blue.*

101. **Acids.**—An *acid* is a compound of hydrogen, which hydrogen can be replaced by a metal; as, hydrochloric acid (HCl); sulphuric acid (H_2SO_4); nitric acid (HNO_3). Acids possess a sharp sour taste, have the power of turning blue litmus red, decompose carbonates setting free carbonic acid gas, form salts with bases, and neutralise alkalis.

Test for Acids.—*Acids turn blue litmus paper red.*

102. **Salts.**—A *salt* is the compound formed, when the

hydrogen, of an acid is partially or wholly replaced by metals; as zinc sulphate ($Zn\ SO_4$); calcium chloride ($CaCl_2$), common salt ($NaCl$); potassium hydric sulphate ($KHSO_4$).

Expt. 78.—Take a little caustic potash solution in a test-tube and add to it a few drops of litmus solution. Then gently pour some nitric acid in. The blue litmus solution will turn red, because the acid neutralizes the alkali. Boil off the liquid in a small porcelain dish. A white salt will be left. This is nitre, formed by the chemical combination of nitric acid and caustic potash. If after heating the salt strongly, dissolve a little of it in water. The solution will neither turn red litmus blue, nor blue litmus red. Thus, we see that acids neutralize alkalis and form neutral salts.

$$HNO_3 + KOH = KNO_3 + H_2O$$

Nitric acid	caustic potash	nitre	water
An acid; turns blue litmus red.	An alkali; turns red litmus blue.	A salt; is neutral; has no action on litmus.	

Note.—If all the atoms of hydrogen of an acid are replaced by a metal, the salt is called a *normal* or *neutral salt*. This has neither an acid nor an alkaline reaction on litmus paper.

$$2\,HCl + CaO = CaCl_2 + H_2O$$

$$H_2SO_4 + Fe = FeSO_4 + H_2$$

Phosphoric acid.	Caustic potash.	Potassium phosphate.	Water.

$$H_3PO_4 + 3\,KOH = K_3PO_4 + 3\,H_2O$$

$$H_2CO_3 + Na_2O = Na_2CO_3 + H_2O$$

If the hydrogen of an acid is only partially replaced by metals, the salt thus formed is called an *Acid salt*. This class of salts has an acid reaction.

$$KOH + H_2SO_4 = H_2O + KHSO_4$$

Questions.

1. Define the terms:
   (*a*) An oxide, a base and an anhydride.
   (*b*) An acid, an alkali and a salt? Give examples.

*2. What takes place when (a) Potassium is thrown on water.

(b) Phosphorus is burnt in a bell-jar placed over water and the white fumes allowed to cool.

(c) The liquids thus obtained are mixed, and then evaporated to dryness?

3. Calculate (a) the weight of caustic potash required to neutralize 100 lbs. of nitric acid, and (b) the weight of the salt thus produced.

4. What are the tests for acids and alkalis?

5. Describe an experiment to show that alkalis neutralize acids.

6. What takes place when carbon dioxide is successively passed into warm solutions of (1) nitre, (2) caustic soda, (3) lime?

CHAPTER XIV.

CARBON: *Symb. C.; At. Wt. 12.*

103. **Occurrence of carbon.**—Carbon exists both free and combined in nature. It exists in the free state as diamond, graphite and coal. It is found combined, as carbon di-oxide in air and as carbonates in lime-stone-rocks and sea-shells. It is the chief constituent of animal and vegetable bodies.

104. **Animal and vegetable matter contain carbon.**

Expt. 79—A piece of meat is converted into charcoal, when it is partly burnt over a fire.

Expt. 80.—Pour some strong sulphuric acid on a lump of white sugar; it becomes dark, froths up, and is converted into black carbon.

105. **Varieties of carbon, and how they differ.**

(i) Crystalline: { Diamond, Graphite.

(ii) Amorphous or Non-crystalline: { Coal, Charcoal.

DIAMOND.	GRAPHITE *(Plumbago.)*	CHARCOAL.
(1) is colourless.	is greyish black.	is black.
(2) possesses a very brilliant lustre.	has a faint metallic lustre.	is dull.
(3) occurs in octahedral crystals.	occurs crystalline in six-sided plates.	is amorphous.
(4) is non-porous.	is slightly porous.	is porous.
(5) has a Sp. Gr. of 3·5.	has a Sp. Gr. of 2·2.	has a Sp. Gr. of 1·5, when air is removed.
(6) is a bad conductor of electricity.	is a semi-conductor of electricity.	is a good conductor of electricity.
(7) is the hardest substance known.	is soft and has an oily touch.	is soft and brittle.
Uses. (1) From its hardness, it is used for cutting sheets of glass. (2) From its brilliant lustre, it is used for ornamental purposes.	**Uses.** It is largely used (1) in the manufacture of black-lead pencils, (2) for polishing gunpowder, (3) for coating iron work to prevent rusting, (4) for the manufacture of crucibles, (5) as a lubricant for machinery, where oil is inadmissible on account of high temperature.	**Uses.** It is used (1) as a disinfectant for removing offensive vapours from the air, (2) in sugar refining to remove all colouring matter, (3) as water-filter, (4) in the manufacture of gunpowder.

Note.—Graphite can be prepared artificially by dissolving charcoal in molten iron.

106. **General properties of the different forms of carbon.**—(1) They are tasteless, inodorous and infusible. (2) They are insoluble in all known liquids. (3) They are not capable of uniting with any element at the ordinary temperature. (4) When heated in air, they all pass off into carbon di-oxide. They are all bad conductors of heat.

Carbon is a reducing agent.

Expt. 81.—Put some finely powdered oxide of lead (litharge) in a hole made in a bit of charcoal and heat it in the luminous flame with the blow-pipe; globules of metallic lead will be obtained.

$$\underset{\text{Litharge.}}{2\,PbO} + \underset{\text{Carbon.}}{C} = \underset{\text{Lead.}}{2\,Pb} + \underset{\text{Carbon di-oxide.}}{CO_2}$$

107. **Diamond, graphite, and charcoal are chemically the same substance.**—When any of the three forms diamond, graphite, or pure charcoal is burnt in a vessel filled with pure oxygen, nothing else than carbon di-oxide is formed. Further, for the same weight of each of these three substances the same weight of the gas is produced. Thus, 12 parts by weight of graphite, diamond, or amorphous carbon, yield 44 parts, by weight of carbon di-oxide and nothing else.

108. **Varieties of charcoal.**—(*a*) *Wood charcoal* is prepared by heating heaps of wood without a free supply of air.

(*b*) *Animal charcoal*, or bone-black is prepared by charring bones in closed iron retorts. It consists of a mixture of very porous charcoal and phosphate of lime. It is used for decolourizing raw sugar.

(*c*) *Lamp-black* or soot is prepared by burning resin or turpentine,—substances rich in carbon, with a limited

supply of air and bringing a cool surface into the flame. It is used for printer's ink and for black paint.

(*d*) *Coke* is an impure form of carbon left behind, when coal is heated in closed vessels as in the manufacture of coal gas. It is largely used in smelting iron.

Questions.

* 1. What are the different forms in which free carbon occurs in nature, and how do these forms differ from each other? In combination with what other elements does carbon exist in animal and vegetable matter, and how do plants obtain their carbon? Mention two other elements which, like carbon, exist free in more than one form.

* 2. Diamond, black-lead, and charcoal are said to be chemically the same substance. How can it be shown that this is the case?

3. Describe an experiment to show that vegetable matter contains carbon.

* 4. By what names are the different varieties of carbon known, and how do they differ from one another? How can it be proved that they all consist of the same element?

5. How are lamp-black and bone-black prepared? For what purpose is each used? Explain the difference between "charring flesh" and "burning it completely."

6. Describe experiments to illustrate the fact that hydrogen and carbon are reducing agents.

CHAPTER XV.

CHLORINE: *Symb. Cl.; At. Wt. 35·5.*

109. **Occurrence.**—Chlorine is never found *free* in nature. It chiefly occurs in combination with the element sodium, as common or rock salt (Na Cl).

110. **Preparation.**—(i) When a mixture of common salt, manganese di-oxide and dilute sulphuric acid is heated in a flask provided with a safety funnel and a bent-tube, chlorine is given off as a greenish yellow gas and is collected in dry bottles by downward displacement.

Sodium chloride.	Manganese di-oxide.	Sulphuric acid.	Sodic Hydrogen Sulphate.	Manganese Sulphate.	Water.	Chlorine.

$$2NaCl + MnO_2 + 3H_2SO_4 = 2NaHSO_4 + MnSO_4 + 2H_2O + Cl_2$$

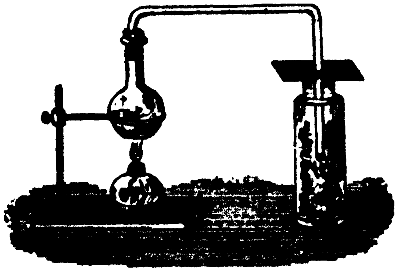

Fig. 23.

(ii) It may also be prepared by gently heating a mixture of manganese di-oxide and hydrochloric acid.

Manganese di-oxide.	Hydrochloric acid.	Manganese chloride.	Water.	Chlorine.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2$$

Note.—In the latter re-action, only half the quantity of the chlorine comes off as gas.

111. **Properties.**—(1) Chlorine is a dense greenish yellow gas with a strong suffocating smell.

(2) When breathed, it produces coughing and inflammation of the throat, and sometimes even death.

(3) It is nearly $2\frac{1}{2}$ times as heavy as air, and is therefore collected by downward displacement.

(4) It is soluble in cold water to a considerable extent, one volume of water dissolving three volumes of the gas.

Hence the gas cannot be prepared over water. The solution known as chlorine-water has the smell of the gas. If exposed to sunlight, it slowly undergoes decomposition, chlorine combining with the hydrogen of the water to form hydrochloric acid and the oxygen being set free.

(5) It is not inflammable but supports the combustion of many bodies.

Expt. 82.—Plunge a lighted taper into a jar of chlorine. It burns with a lurid flame, emitting a dense smoke of carbon and forming fumes of hydrochloric acid.

Expt. 83.—When a piece of dry phosphorus is placed into a bottle of chlorine gas, it takes fire and burns with a pale greenish flame, while suffocating fumes of phosphoric chloride (PCl_5) are formed.

(6) Chlorine has a most powerful affinity for hydrogen and for metals in a finely divided state.

Expt. 84.—Sprinkle a little powdered antimony into a jar of chlorine. Sparks of fire are seen and dense, white, suffocating fumes of antimony chloride ($SbCl_3$) are formed.

Expt. 85.—When a strip of blotting paper dipped in warm oil of turpentine is plunged into a bottle of chlorine gas, it immediately bursts into flame, forming hydrochloric acid and depositing soot.

(7) It bleaches vegetable colours when moist, but not mineral colours.

Note.—*The bleaching action of chlorine is as follows:* On account of its strong affinity for hydrogen, chlorine unites with the hydrogen of the water to form hydrochloric acid, setting free oxygen as a gas. The liberated oxygen combines with the colouring matter and forms compounds which happen to be colourless.

The presence of chlorine is detected by (1) its greenish yellow colour, (2) by its bleaching action, (3) by the sparks of fire seen when antimony powder is sprinkled into it.

Uses. (1) From its energetic chemical union with other elements, chlorine is used as a disinfectant. It readily destroys noxious germs and converts offensive gases into harmless substances. (2) It is extensively used for bleaching purposes in the manufacture of cotton goods and paper, in calico-printing, and in dyeing.

112. **Bleaching Powder.**—This is a compound of calcium chloride and calcium hypo-chlorite, having the

formula $CaCl_2O$. It is obtained by passing chlorine gas through boxes containing slaked lime.

Expt. 86.—Soak the goods to be bleached alternately for some time in a solution of bleaching powder and in water rendered sour with a little sulphuric acid. The acid sets chlorine free which, from its strong attraction for hydrogen, decomposes water, liberating oxygen. This nascent oxygen combining with the colouring matter bleaches the substance.

Bleaching powder contains chlorine.

Expt. 87.—Take a little of the white bleaching powder and pour on it a little dilute sulphuric acid; yellow chlorine gas is given off at once, which will be found to bleach.

$$CaCl_2O + H_2SO_4 = Ca\,SO_4 + H_2O + Cl_2.$$

118. **Hydrochloric acid** (HCl).—(i) *Preparation: Expt.* 88.—Put a few grains of common salt in a large flask and pour over it double the weight of strong sulphuric acid. Hydrochloric acid gas comes off slowly, but rapidly when heated. The gas is collected in dry bottles by downward displacement. The liquid acid is only a solution of the gas in water.

Sodium chloride.		Sulphuric acid.		Hydrochloric acid.		Sodium sulphate.
$2NaCl$	$+$	H_2SO_4	$=$	$2HCl$	$+$	Na_2SO_4.

(ii) *Properties.*—(1) Hydrochloric acid gas is transparent and colourless. (2) It has a pungent irritating smell. (3) In contact with moist air, it forms dense fumes. (4) It is heavier than air. (5) It is very soluble in water, one volume of water dissolving 500 volumes of the gas at 0°C. (6) It does not burn, nor does it allow a candle to burn in it.

(iii) *Chemical conduct of hydrochloric acid.*

(*a*) The acid gives up its hydrogen when brought in contact with certain metals as zinc, iron, &c., and the chlorine unites with the metals to form chlorides.

$$Zn + 2HCl = ZnCl_2 + H_2.$$

(*b*) In contact with substances like manganese di-oxide which readily give up their oxygen, it parts with its chlorine, while the hydrogen combines with oxygen to form water.

$$MnO_2 + 4HCl = MnCl_2 + 2H_2O + Cl_2.$$

(*c*) When it acts upon metallic oxides such as lime (CaO), magnesia (MgO) &c., which do not easily give up their oxygen, the hydrogen of the acid combines with the oxygen of the oxide to form water, while the metals combine with chlorine to form chlorides.

$$MgO + 2HCl = MgCl_2 + H_2O.$$

(*d*) When the acid acts upon a carbonate, carbon di-oxide is given off as a gas, while the chloride of the metal is left behind.

$$MgCO_3 + 2HCl = CO_2 + MgCl_2 + H_2O.$$

(*e*) When the acid acts upon sulphides, hydrogen sulphide is given off.

$$FeS + 2HCl = FeCl_2 + H_2S.$$

Questions.

• 1. How is chlorine prepared, and what are its most important properties and uses? Express by means of a chemical equation the re-actions which take place in its preparation.

• 2. What non-metallic element can be separated from common-salt and how? Describe the properties of this element and mention a chemical test by which its presence in common-salt is proved.

• 3. Name the gas which is given off when sulphuric acid is heated with common salt and black oxide of manganese, and state how blue litmus would be affected by an aqueous solution of the gas. **Ans.** The litmus will be bleached.

4. Describe the changes that take place and the substances formed, when

• (i) Powdered antimony is thrown into a bottle of chlorine.
(ii) An aqueous solution of chlorine is exposed to sun-light.
• (iii) Common salt is heated with sulphuric acid.
(iv) Manganese di-oxide is heated with hydrochloric acid.

• 5. What is bleaching powder and how is it prepared? What takes place when sulphuric acid is added to it? In what manner are the two substances mentioned used in the process of bleaching?

* 6 Give the ordinary method of preparation and the chief properties of hydrochloric acid.

7. Explain with equations the chemical action of hydrochloric acid upon (*a*) Carbonates, (*b*) oxides, and (*c*) metals, (*d*) sulphides.

8. Calculate the weights of common-salt and oil of vitriol required to produce 20 lbs. of hydrochloric acid.

* 9. Give the distinctive properties of hydrogen, chlorine and carbonic acid gas. State how you would collect each of these gases.

10. Explain clearly the bleaching action of chlorine.

CHAPTER XVI.

SULPHUR: *Symb. S.; At. Wt. 32.*

114. **Occurrence.**—Sulphur exists both free and combined. Free, it is chiefly found in volcanic countries such as Sicily. Combined, it exists in the form of sulphides and sulphates. It is also found in the white of an egg and in the flesh of animals.

The chief natural sulphides are:—Iron pyrites (FeS_2), copper sulphide (CuS), galena (PbS), cinnabar (HgS), and blende (ZnS.)

The chief sulphates are gypsum ($CaSO_4$), glauber's salt ($Na_2 SO_4$), Epsom salts ($Mg SO_4$), heavy-spar ($Ba SO_4$), blue-stone ($Cu SO_4$), green vitriol ($Fe SO_4$), white vitriol ($Zn SO_4$), lead sulphate ($PbSO_4$).

115. **Extraction.**—The ores of sulphur are burnt in heaps, without free access of air; when, part of the sulphur burns and the heat thus furnished melts the remaining part into what is called crude brimstone. This is then refined by distillation. If the vapour gets suddenly cooled, it is deposited in the form of a fine powder consisting of minute crystals, and is called *flowers* of sulphur. If the vapour is condensed into a liquid and cast in moulds, we have roll-sulphur or sulphur-sticks.

116. **Different forms.**—Sulphur exists in four allotropic modifications:

(i) ***Rhombic Octahedral Crystals.***—This form is found in

nature. It is also obtained when a solution of flowers of sulphur in carbon disulphide is allowed to evaporate.

(ii) *Needle-shaped* or Prismatic *sulphur*.—This form is obtained when sulphur is melted and allowed to crystallize.

(iii) *Plastic sulphur*.—This is obtained when melted sulphur is cooled suddenly by being plunged into water.

(iv) *White amorphous sulphur*.—This is obtained by treating flowers of sulphur which usually contains about 5 % of amorphous sulphur with carbon di-sulphide; when, the rhombic variety is dissolved; the white amorphous substance which is insoluble in that liquid is left behind.

To these may be added *Flowers of sulphur* and *Roll sulphur*.

117. **Properties.**—(1) Sulphur or brimstone is a yellow brittle solid.

(2) It is insoluble in water; but soluble in carbon di-sulphide and oil of turpentine.

(3) It is highly inflammable, and burns with a pale blue flame emitting suffocating vapours of sulphurous anhydride (SO_2).

(4) It combines readily with many metals, when hot, forming sulphides and giving out much heat in the process.

Expt. 89.—When sulphur is heated in air, it first melts, the colour turning brown and dark; then it becomes very viscous. When further heated, it becomes again fluid and finally burns with a pale blue flame producing suffocating fumes of sulphur di-oxide (SO_2).

Note.—If sulphur is heated in a tube without free supply of air it gives off yellowish brown vapours of the element.

Uses of sulphur.—Sulphur is used (1) in the preparation of matches to help the wood to take fire, (2) in the manufacture of gunpowder, (3) in the preparation of sulphuric acid, and (4) for fumigation.

118. **Oxides of Sulphur.**—Sulphur forms two oxides, sulphurous anhydride or sulphur di-oxide (SO_2), which

when dissolved in water gives sulphurous acid (H_2SO_3), and sulphuric anhydride (SO_3), which furnishes sulphuric acid (H_2SO_4) combining with water.

Sulphur di-oxide.—This is formed when sulphur is burnt in air, or in oxygen. It is best prepared by heating copper and strong sulphuric acid in a flask, and is collected in dry bottles by downward displacement.

$$2H_2SO_4 + Cu = CuSO_4 + SO_2 + 2H_2O.$$

Properties: (1) It is a colourless gas having the pungent and suffocating smell of burning sulphur. (2) It is soluble in water, one volume of water dissolving nearly 50 volumes of it. (3) It is neither a combustible substance nor a supporter of combustion. (4) It bleaches readily in the presence of water, and stops fermentation.

Uses.—It is extensively used (1) for bleaching wool, silk, paper, straw, etc., (2) to preserve liquids which have a tendency to undergo fermentation, (3) as a disinfectant, and (4) in the manufacture of sulphuric acid.

Note.—The points of difference between the bleaching action of chlorine and that of sulphur di-oxide:—

(*a*) *Chlorine* bleaches by oxidation. That is, chlorine combines with the hydrogen of the water and sets free oxygen. This oxygen, combining with the colouring matter, destroys the colour.

$$2Cl_2 + 2H_2O = 4HCl + O_2$$

The dioxide bleaches by reduction. That is, it absorbs oxygen from the water to form sulphuric acid and sets free hydrogen. This latter combines with the colouring matter and destroys the colour forming colourless compounds.

$$SO_2 + 2H_2O = H_2SO_4 + H_2$$

(*b*) The substances bleached by sulphur di-oxide can be restored to their original colour by dipping them in an alkali such as ammonia; whereas, in the other case this cannot be.

119. **Sulphuric acid** or **Oil of Vitriol.**—(i) *Preparation.*—Large quantities of sulphur, or iron pyrites (FeS_2) are burnt in furnaces; when, sulphur di-oxide is formed.

The oxide thus formed is conducted into large leaden chambers where vapours of nitric acid, steam, and air are passed. These mixing freely produce sulphuric acid.

Note.—Like the other acids, it cannot easily be prepared from its salts, but it is made exclusively by oxidizing sulphur di-oxide in the presence of water.

(ii) *Properties:* (1) Sulphuric acid is a dense oily-looking colourless liquid having a Sp. Gr. of 1·84. (2) It has a strong affinity for water, and produces much heat when mixed with it. (3) It is intensely caustic and chars almost all vegetable and animal substances, on account of its attraction for moisture.

(iii) *Uses.*—It is used (1) for drying gases; (2) for the preparation of the other acids and sulphates; (3) in soap-making, dyeing, calico-printing and bleaching; and (4) for generating electricity in voltaic batteries.

Note.—*A sulphide* is a compound of sulphur with any other element; as, carbon di-sulphide (CS_2), lead sulphide.

A sulphite is a compound obtained by the action of sulphurous acid on a metal or its base; *e.g.*, sodium sulphite (Na_2SO_3).

A sulphate is a compound furnished by the action of sulphuric acid upon a metal or its base; *e.g.*, blue stone ($CuSO_4$).

Test for Sulphuric acid.—Add barium nitrate to it; a white precipitate of the insoluble sulphate is formed.

120 **Hydrogen Sulphide** (H_2S).—It is commonly called sulphuretted hydrogen. It is prepared by the action of dilute sulphuric acid or hydrochloric acid on ferrous sulphide (FeS).

$$FeS + H_2SO_4 = FeSO_4 + H_2S.$$

$$FeS + 2HCl = FeCl_2 + H_2S.$$

Properties: (1) Hydrogen sulphide is a colourless gas, but has the disagreeable smell of rotten eggs and is very poisonous, if breathed.

(2) It is soluble in cold water to a considerable extent.

(3) It burns in air with a pale bluish flame forming water and sulphur di-oxide, but does not support combustion.

(4) It brings down many metals from solutions of their salts in the form of sulphides insoluble in water.

Tests: (1) Hydrogen sulphide may be detected by its smell of rotten eggs.

(2) When a piece of paper, moistened with a solution of lead acetate is held over the gas, the paper is stained black.

121. **The distinguishing Properties of the three chief acids.**

SULPHURIC ACID (OIL OF VITRIOL.)	NITRIC ACID (AQUAFORTIS.)	HYDROCHLORIC ACID (MURIATIC ACID.)
Colourless liquid.	Colourless liquid.	Colourless gas.
Sp. Gr. = 1·8.	Sp. Gr. = 1·5.	Soluble in water.
Does not fume in air.	Fumes in air.	Fumes in air.
No action on indigo.	Bleaches indigo.	No action on indigo.
Chars organic matter.	Stains organic matter yellow.	....
Dissolves copper when heated, giving off sulphurdi-oxide and forming copper sulphate.	Dissolves copper without heat, giving off reddish brown fumes and forming copper nitrate.	No action on copper.
Test. Add barium nitrate; a white precipitate is produced.	The black ring with Ferrous sulphate solution. *Expt.* 77.	Gives off chlorine when heated with manganese di-oxide.

Questions.

* 1. In what forms is sulphur usually met with? Mention some of the principal uses to which this element is put. How may sulphur be made to combine with copper, and what weight of it should be taken in order that 50 lbs. of copper may be so combined?

2. How is sulphur extracted from its ores? Describe carefully what takes place when (1) sulphur; (2) iron pyrites are heated in air.

3. How is sulphur di-oxide prepared? How does its bleaching action differ from that of chlorine?

4. Describe how sulphuric acid can be made. What are its chief properties? For what purposes is it used?

5. What is the difference between a sulphide, a sulphite and a sulphate? Give the composition of: sulphuretted hydrogen, brimstone, sulphurous acid, heavy spar, blende, and iron pyrites.

* 6. State the following particulars concerning sulphuretted hydrogen: (*a*) its colour; (*b*) its smell; (*c*) will it allow a lighted candle to burn in it? (*d*) will it take fire on application of a flame? (*e*) if you were making it, would you try and collect it over water?

CHAPTER XVII.

PHOSPHORUS AND SILICON.

PHOSPHORUS: *Symb. P.; At. Wt. 31.*

122. **Occurrence.**—Phosphorus is never found free in nature. It occurs combined in the form of phosphates, the chief of which is bone-ash or calcium phosphate, $Ca_3(PO_4)_2$. It is also met with in the seed of plants. There are two varieties of phosphorus, yellow and red.

123. **Preparation.**—Phosphorus is chiefly obtained from bone-ash, the white porous mass left behind, when bones are burnt in air. The ash is treated with sulphuric acid, and the substance thus formed is mixed with charcoal and strongly heated in a retort; phosphorus distils over, and is cast into sticks under cold water. This is the ordinary or *yellow phosphorus.*

Note.—When bones are heated in closed vessels, it is converted into bone or animal charcoal.

Red Phosphorus is formed when ordinary phosphorus is exposed to light, or heated in closed vessels without access of air.

124. **Properties and uses.**

Yellow Phosphorus.	Red Phosphorus.
(1) is of a faint yellow colour.	is of a dark red colour.
(2) is a soft, semi-transparent, waxy-looking substance.	is an opaque, powdery substance.
(3) is very active combining eagerly with oxygen, chlorine, iodine, etc.	is very inactive.
(4) is extremely inflammable and takes fire at a low temperature of 44°C. Hence it is kept under water.	is not highly inflammable. It may be heated in the air above 200°C. without taking fire. Hence it can be exposed to the air without danger.
(5) is feebly luminous in the dark.	is not luminous in the dark.
(6) is very poisonous.	is not poisonous.
(7) is not soluble in water, but dissolves in carbon di-sulphide.	is insoluble both in water and in carbon di-sulphide.
(8) has a Sp. Gr. of 1·8.	has a Sp. Gr. of 2·1.
(9) is crystalline.	is amorphous.
(10) is employed in the manufacture of *common* lucifer matches.	is used in the manufacture of *Safety* matches.

125. **Yellow Phosphorus is very inflammable.**—*Expt.* 90. Take a bit of yellow phosphorus and wrap it in a piece of blotting paper. Then rub it with a hammer on a piece of wood. The rubbing will cause the phosphorus to take fire and burn.

Expt. 91. Put a bit of dry yellow phosphorus on to an iron tray. Next place a bit of red phosphorus of the same size also

on the tray. Heat the tray. In a few instants the yellow phosphorus will take fire and burn with a bright flame and give off dense white fumes. But the red phosphorus catches fire and burns exactly like the other only after it has been heated for some time.

126. **Preparation of Matches.**—1. *Ordinary Matches.* The prepared wooden splints are first dipped in melted sulphur and are then tipped with a mixture of yellow phosphorus, potassium chlorate, fine sand, lead per-oxide and glue. As the red tip of the match contains phosphorus, it takes fire when rubbed on any rough surface.

2. *Safety Matches.*—The prepared wooden sticks are first dipped in melted sulphur by which they are rendered readily inflammable. These are then tipped with a paste consisting of potassium chlorate, antimony sulphide, powdered glass and gum-water. They are ignited by being rubbed on a side of the box covered with a mixture of red phosphorus, powdered glass, manganese di-oxide, and glue. The tip of the safety match contains no phosphorus, and therefore it does not take fire except when rubbed on the prepared side which contains phosphorus.

SILICON: *Symb. Si.; At. Wt. 28.*

127. **Occurrence.**—Silicon does not exist free in nature. It occurs chiefly in the form of the oxide, silica (SiO_2), known as sea-sand, quartz or rock-crystal, flint, and agate; and in combination with oxygen and several of the common metals as silicates. It is prepared by separating oxygen from silica. There are two varieties of silicon, amorphous and crystalline.

128. **Properties.**—*Amorphous* silicon is a black powder which burns when heated in air or oxygen. *Crystallized* silicon is a brilliant grey substance. It is very hard being capable of scratching glass. It does not burn in air or oxygen, even when strongly heated. Both the forms are

insoluble in water and in all acids except hydrofluoric acid (HF.)

129. **Glass** is a double silicate obtained by fusing in a hot furnace a mixture either of white sand, lime, and soda, or of sand, oxide of lead and potash.

Varieties of Glass:—1. Crown or window and plate glass is made by fusing together white sand, slaked lime and soda. It is fusible and is used for chemical apparatus.

2. *Bohemian* glass consists of white sand, potash and lime. This is not easily fusible. This is employed when hard glass is needed for combustion tubes.

3. *Flint* glass or crystal is composed of white sand, potash, and red lead. It is used for common glass articles.

4. *Common bottle* glass is composed of white sand, soda, lime, iron oxide and alumina.

Properties of glass.—(1) Glass is a brittle solid, (2) conducting heat and electricity badly. (3) In the melted state, it is capable of dissolving many oxides, but on that account it does not lose its transparency, though it becomes variously coloured. (4) It is not acted upon by any acid except by hydrofluoric acid.

130. **Compounds.**—1. *Quartz* (SiO_2) is a common crystalline form of silica. *Rock-crystal* is a pure transparent variety of quartz and is used under the name of Brazilian pebble to form lenses for spectacles .

2. *Sand* (SiO_2) is largely composed of grains of quartz that have been worn more or less round by rubbing. *Sandstone* has been formed by the grains of sand becoming united under great pressure by some cementing substance.

3. *Flint* (SiO_2) is a dark-coloured, non-crystalline, impure variety of silica.

4. *Clay* (Al_2O_3, $2SiO_2$, $2H_2O$) is a silicate of alumina. So are bricks, pottery, and china which are formed from clay. It is plastic and impervious to water.

Note.—*A silicate* is a compound of silica with metals.

Questions.

1. Which is the chief material from which phosphorus is prepared and how is it prepared?

* 2. State how the two varieties of phosphorus differ from each other, and describe how each variety is employed in the manufacture of lucifer matches.

* 3. Describe carefully what takes place when (1) yellow phosphorus is exposed to the air and (2) red phosphorus is heated in air.

* 4. What is rock-crystal? Describe an experiment by which diamond may be distinguished from rock-crystal.

Ans. (i) When heated in air diamond loses its lustre, becomes black, swells up, and is finally converted into carbonic acid gas, without any residue; but rock-crystal (SiO_2) neither loses colour nor changes its composition, even when burnt in air.

(ii) Pure diamond is not at all acted upon by hydrofluoric acid; while rock-crystal readily dissolves in the acid.

5. How is silicon prepared? Mention its chief properties.

6. (*a*) What is *glass*? Name the different varieties of glass, and state from what materials each is prepared and to what purpose each is used. (*b*) Name some varieties of silica? What is a silicate?

CHAPTER XVIII.

CHEMICAL ACTION AND ITS LAWS.

131. **Kinds of chemical action.**—The numerous cases of chemical change may be referred to one or other of the following modes of action:—

(i) *Combination* of entire molecules or formation of a compound by synthesis.

$$Cu + S = CuS$$

$$CaO + H_2O = Ca(OH)^2$$

(ii) *Decomposition* or splitting up of a compound molecule into its elements or into simpler molecules.

$$CaCO_3 = CaO + CO_2$$
$$2HgO = 2Hg + O_2$$

(iii) *Single displacement* or decomposition by substitution.

$$Zn + HSO_4 = ZnSO_4 + H$$

(iv) *Double decomposition.*—Two or more molecules coming together exchange some of their constituents so as to give rise to the same number, or to a greater number of molecules.

$$\left.\begin{array}{r} CaCO_3 + 2HCl = CaCl_2 + H_2CO_3 \\ H_2CO_3 = CO_2 + H_2O. \end{array}\right\}$$
$$i.e., \; CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O.$$
$$\left.\begin{array}{r} \text{Again, } 2NaCl + H_2SO_4 = 2HCl + Na_2SO_4. \\ 2HCl + MnO_2 + H_2SO_4 = MnSO_4 + Cl_2 + 2H_2O. \end{array}\right\}$$
$$i.e., \; 2NaCl + MnO_2 + 2H_2SO_4 = Na_2SO_4 + Cl_2 + MnSO_4 + 2H_2O$$

132. Conditions favourable for chemical change.

(i) *Use of physical agents.*—1. *Heat* promotes chemical-change.

Expt. 92.—Mix some nitre and charcoal powder together. No change will be noticed however long they remain together. Heat the mixture. The charcoal will now burn combining with the oxygen of the nitre to form carbon di-oxide.

2. *Light.*—Sunlight helps chemical action.

Expt. 93.—Mix chlorine and hydrogen together: no chemical action takes place in the dark. Expose the mixture to light; the hydrogen and chlorine combine together and form hydrochloric acid.

3. *Electricity* aids chemical action. *Vide* Expt. 22.

(ii) *Close contact.*—1. *Direct contact* is necessary for chemical change.

Expt. 94.—Keep a piece of phosphorus under water. It undergoes no chemical change, since contact with air is removed. Take it out; it readily takes fire combining with the oxygen of the air.

2. *Solution* aids chemical change. *Vide* Expt. 6.

3. *A solid in the state of powder* readily undergoes chemical change.

Expt. 95.—Throw some copper foil into a jar of chlorine: no action takes place. Break the foil into very fine powder and sprinkle the powder into the jar; sparks of fire are seen.

Note.—As a general rule, chemical change proceeds more rapidly between a solid and a liquid, or a solid and a gas than between solids.

(iii) *Nascent state* of elements is favourable for chemical action.

Expt. 96.—Place a coloured wet chintz in a bottle of oxygen; it is not bleached. Place the chintz in a bottle of chlorine: it becomes bleached. Chlorine, combining with the hydrogen of the water, sets free oxygen; the oxygen, now in the nascent state, unites with the colouring matter to form colourless compounds.

Note. An element is said to be in the *nascent* state, when it is just liberated from a compound (Nascent = just born).

(iv) *The presence of a catalytic substance.*—The presence of manganese di-oxide assists the decomposition of potassium chlorate at a low temperature.

Note.—The action of sulphuric acid on zinc or iron is helped by the presence of water.

(v) *Unlike nature.*—The most unlike substances combine together most readily.

(a) Tin and lead are more like each other in their properties than oxygen and hydrogen. They do not form any compound, differing in essential properties from the original substances. But hydrogen and oxygen unite readily to form water whose properties are quite different from the component elements.

(*b*) Acids and alkalis are substances most unlike each other, and they readily combine with each other forming salts which have quite different properties from either of them. Thus, caustic potash is alkaline, and nitric acid is acid; but when these two substances are mixed together, they readily combine to form nitre, a neutral salt which entirely differs in its properties from either of the two substances from which it results.

(*c*) Potassium and sodium resemble each other. They do not form any compound. On the other hand, they have quite different properties from water. and they readily combine with it.

133. The Physical and other changes that accompany chemical changes.

(1) *Heat is felt when chemical union takes place.* Vide Expt. 16.

(2) *Light is sometimes given off.*

When powdered antimony is thrown into a bottle of chlorine gas, sparks of fire are seen.

(3) *Electricity is generated.*

In a voltaic cell, electricity is produced by the chemical action of dilute sulphuric acid upon the zinc plate.

(4) *Contraction of volume is noticed.* Vide § 18 Note.

(5) *Change of state.*

Oxygen is a gas. Mercury is a liquid; but when these two unite chemically, we have a solid powder called red oxide of mercury.

(6) *Change of physical properties.*

(*a*) Change of colour.—Carbon is black; sulphur is yellow; but their compound, carbon di-sulphide (CS_2) is colourless.

(*b*) Smell.—Neither nitrogen nor hydrogen has any smell; but ammonia (NH_3), a compound of the two elements has a pungent smell.

(*c*) Sometimes poisonous compounds result from altogether harmless elements Thus hydrogen, carbon, and nitrogen are harmless substances, but hydrocyanic acid, a compound of these three is poisonous.

134. **Characteristics of Chemical Changes.**—(1) *The formation of new products which differ in physical and chemical properties from those which enter into the change.* When phosphorus is burnt in air, it becomes phosphoric anhydride (P_2O_5). It is neither combustible nor a supporter of combustion; but phosphorus is combustible and oxygen is a supporter of combustion. Similarly, when chalk ($CaCO_3$) is heated, it is converted into lime (CaO), carbon dioxide (CO_2) escaping as a gas. Quick-lime has a strong attraction for water, while chalk has not.

(2) *A thermal effect, either the evolution or the absorption of heat.* When strong sulphuric acid is mixed with water, much heat is felt.

(3) *Substances undergoing chemical changes, do so obeying certain laws of chemical combination.*

135. **The laws of chemical combination.**—(1) The law by fixed or definite proportion.—*The same chemical compound always contains the same elements united together in the same proportions*; in other words, *the proportions, in which substances unite together, are fixed and invariable.* Thus, water (H_2O) always consists of 16 parts, by weight of oxygen united with 2 parts by weight of hydrogen. Similarly, nitrogen monoxide (N_2O) is always formed by the union of 16 parts by weight of oxygen with 28 parts by weight of nitrogen and in no other ratio.

(2) The law of multiple proportions.—*When several compounds of the same two elements exist, the numbers denoting their proportions by weight are simple multiples of their combining weights.*

This law may also be stated as follows:—*When an element combines with another in more than one proportion, the different weights of one of the elements which unites with a constant quantity of the second element bear a simple ratio to one another, i.e.*, the different higher proportions

are always products of the lowest proportion by an integer.

Nitrogen forms 5 compounds with oxygen.

N_2O	Nitrogen	monoxide	28	:	1×16
N_2O_2	,,	di-oxide	28	:	2×16
N_2O_3	,,	tri-oxide	28	:	3×16
N_2O_4	,,	tetr-oxide	28	:	4×16
N_2O_5	,,	pent-oxide	28	:	5×16

Each of the above compounds contains 28 parts by weight of nitrogen united with 1×16; 2×16; 3×16; 4×16; 5×16 parts, by weight of oxygen respectively.

From this we learn that the relative proportions of oxygen in combination with a constant weight of nitrogen are as $1 : 2 : 3 : 4 : 5$. In other words, the weights of oxygen contained in the four last of these compounds are twice, thrice, four times, and five times that contained in the first compound, that is, simple multiples of 16, the combining weight of oxygen.

Further, it is not possible for us to prepare a compound containing any intermediate quantity of oxygen, or in which a fractional part of 16 is taken. If, for instance, we try to combine 28 parts by weight of nitrogen with 20 parts by weight of oxygen, we get the whole of nitrogen combined with only 16 of the oxygen, the other 4 parts of oxygen remaining uncombined.

The theory, that all atoms are indivisible and of the same size but that atoms of different substances are of different weights, sufficiently accounts for these laws.

***Example* 1.—Two elements A and B combine together in three different proportions by weight as follows :—A, 58·11 and B, 41·89 ; A, 40·96 and B, 59·04 ; A, 73·37, and B, 26·63. Do these elements in these combinations obey the law of combination in multiple proportions?**

In the three combinations, the proportion of A to B is

$$\begin{array}{llll} & \text{A} \quad \text{B} & & \text{A} \quad \text{B} \\ (1) & 58\cdot11 : 41\cdot89 = 1 : \frac{41\cdot89}{58\cdot11} \text{ or } 0\cdot72\ ; & i.e., & 1 : 2 \times 0\cdot36 \\ (2) & 40\cdot96 : 59\cdot04 = 1 : \frac{59\cdot04}{40\cdot96} \text{ or } 1\cdot44\ ; & i.e. & 1 : 4 \times 0\cdot36 \\ (3) & 73\cdot37 : 26\cdot63 = 1 : \frac{26\cdot63}{73\cdot37} \text{ or } 0\cdot36\ ; & i.e., & 1 : 1 \times 0\cdot36 \end{array}$$

Now, the relative proportions of B which combines with a constant weight of A are as 2 : 4 : 1 ; *i.e.*, the different weights of B bear a simple (not fractional) ratio to one another. Hence the elements obey the law of combination in multiple proportions.

Ex. 2.—A chemical compound has the following percentage composition :

Iron 36·84, Sulphur 21·00, Oxygen 42·16

Find its chemical formula.

Now the question amounts to this : find the relative numbers of iron, of sulphur and of oxygen atoms present in the compound. To find this we must ascertain how many times the combining weight of iron (56) is contained in 36·84, how many times that of sulphur (32), in 21·00, and how many times that of oxygen (16) in 42·16.

This information is obtained as below :—

$$\text{Iron } \frac{36\cdot84}{56} = 0\cdot66\ ; \quad \text{Sulphur } \frac{21\cdot00}{32} = 0\cdot66\ ; \quad \text{Oxygen } \frac{42\cdot16}{16} = 2\cdot64.$$

The resulting numbers give the required relation of the number of atoms, but not expressed in the *simplest* ratio in whole numbers. To find the latter, the results must be divided by the smallest ; thus :—

$$\text{Iron } \frac{0\cdot66}{0\cdot66} = 1\ ; \quad \text{Sulphur } \frac{0\cdot66}{0\cdot66} = 1\ ; \quad \text{Oxygen } \frac{2\cdot64}{0\cdot66} = 4.$$

From this we conclude that the compound contains one atom of iron, one of sulphur and four of oxygen. Hence the required formula is $FeSO_4$.

Questions.

* 1. Under what conditions do chemical changes most readily take place? Give a few examples. How would you decide whether

the change which a body has undergone is a chemical or a physical change?

* 2. Illustrate the statement that "Chemical combination takes place most readily between those bodies which least resemble each other."

* 3. Chemical changes are always accompanied by changes of other descriptions. Give some illustrations of these changes and mention the chemical changes which produce them.

4. Illustrate that (1) heat is sometimes necessary to start chemical union; (2) heat is felt when chemical union takes place.

* 5. Mention some of the phenomena which accompany chemical changes. Describe an experiment to illustrate your answer.

* 6. State the two most important laws of chemical combination and explain them by reference to any compounds of Nitrogen.

* 7. When several compounds are formed by the same two elements, in what proportions do these elements exist in the compounds? Explain your answer by means of examples.

* 8. Describe an experiment to show that, when elements combine, the weights in which they do so are in the ratio of their combining weights.

* 9. Two elements A and B combine together in two different proportions by weight as follows: A, 42·86 and B, 57·14; A, 27·27 and B, 72·73. Do these elements in these combinations obey the law of combination in multiple proportions? Give the reasons for your answer.

10. Two elements A and B combine together in three different proportions by weight as follows: A, 21·73 and B, 78·27; A, 52·63 and B, 47·37; A, 35·71 and B, 64·29. Do these elements in these combinations obey the law of combination in multiple proportions? Give reasons.

11. A chemical compound has the following percentage composition:—

$$\left.\begin{array}{ll}\text{Hydrogen} & 2{\cdot}04\\ \text{Sulphur} & 32{\cdot}65\\ \text{Oxygen} & 65{\cdot}31\end{array}\right\}\quad H : S : O = 1 : 32 : 16.$$

Find the formula.

12. A chemical compound has the following percentage composition.

$$\left.\begin{array}{ll}\text{Calcium} & 38{\cdot}7\\ \text{Oxygen} & 41{\cdot}3\\ \text{Phosphorus} & 20{\cdot}0\end{array}\right\}\quad Ca : O : P = 40 : 16 : 31.$$

Find the formula.

CHAPTER XIX.

METALS.†

IRON: *Symb. Fe.; At. Wt. 56.*

136. **Occurrence.**—Iron is one of the most widely distributed metals. It is present in almost all the rocks. It is the most useful metal for man. It exists *free* in meteorites. Pure iron is almost unknown.

Chief ores:

1. Specular iron ore or Red hœmatite (Fe_2O_3)
2. Magnetic iron ore or Lodestone (Fe_3O_4)
3. Spathic iron ore or Clay iron stone ($FeCO_3$)
4. Iron pyrites (FeS_2)

Note.—An ore is a mineral from which a metal can be extracted.

137. **Preparation.**—Pure iron is almost unknown. It is prepared by heating Red hœmatite with charcoal in large furnaces. The oxygen is got rid off as carbonic acid gas and the metal is left behind.

$$2Fe_2O_3 + 3C = 3CO_2 + 4Fe.$$

Note.—When a current of dry hydrogen is passed over red-hot iron-rust, pure iron is left behind.

$$FeO + H_2 = Fe + H_2O.$$

138. **Properties.**—(1) When pure, iron is of a white colour. In dry air and in pure water, it does not lose its brilliancy but it rusts in moist air.

(2) At a high temperature, it burns readily giving off sparks of iron oxide.

(3) When red-hot, it decomposes steam forming magnetic oxide of iron.

(4) It is the hardest and most magnetic of the metals.

(5) It is soluble in all the common acids.

† A metal is an element which has the power to replace the hydrogen of acids to form salts.

139. **Varieties of iron:—(*a*) Cast iron or pig-iron.**—(i) *Composition.*—Cast iron is impure iron containing 90 to 95 per cent. of iron, 2 to 6 per cent. of carbon and a small quantity of silicon, phosphorus and sulphur.

(ii) *Preparation.*—Specular iron ore is heated with limestone and coke in a blast furnace which is so-called, because a blast of air is continually blown in. The iron produced collects in the bottom of the furnace and is drawn off in the liquid condition.

Specular iron ore		Charcoal		Carbon monoxide	Iron
Fe_2O_3	+	$3C$	=	$3CO$	+ $2Fe$

Note 1. The limestone is added as a *flux*, the object of which being to form a fusible substance with the earthy constituents of the ore.

Note 2.—If the ore used is not an oxide, the ore is first calcined, thereby water and carbon di-oxide are expelled, and any sulphides present are oxidized into sulphur di-oxide.

(iii) *Properties.*—(1) Cast iron melts at a lower temperature than either wrought iron or steel. (2) It is hard, non-elastic, very brittle. (3) It has the valuable property of expanding, when melted and allowed to cool. So if run into moulds, it takes impressions even of the finest lines. Hence the name *cast iron*.

(iv) *Uses.*—It is used for making gas and waterpipes, for lamp posts, railings, large wheels, heavy stands for machines,

(*b*) **Wrought iron** or **Soft iron.**—(i) This is nearly pure iron, but it generally contains about 0·2 per cent. of carbon.

(ii) *Preparation.*—It is obtained from cast iron by heating the latter in a special furnace called the puddling furnace, where the carbon and other impurities are burnt away by currents of air.

(iii) *Properties.*—(1) Wrought iron is less fusible than

cast iron or steel. (2) It is tough and not easily broken. When broken, it shows a fibrous structure. (3) It becomes soft at a low heat; hence pieces of it can be forged, welded together, and made to assume any shape we please; hence the name *wrought iron*.

Note.—Wrought iron, when rolled, is called **Bar Iron.**

(iv) *Uses.*—It is used to make nails, horse-shoes, tyres of wheels, ships and boilers.

(*c*) **Steel.**—(i) *Composition.*—Steel contains less carbon than cast iron, but more than wrought iron. In good steel, the quantity of carbon varies from 0·7 to 1·7 per cent.

(ii) *Preparation.*—(1) Steel is obtained from *wrought* iron by heating the latter to redness for some time in contact with coal. (2) It is prepared from *cast* iron by burning out all the carbon and other impurities and then adding as much cast iron as is necessary to give carbon enough to convert the whole mass into steel.

(iii) *Properties.*—(1) Steel is malleable like wrought iron. (2) When broken across, it shows a fine granular structure. (3) It becomes very hard and brittle, when heated and suddenly cooled. This fits it for making it into cutting tools. (4) When cautiously heated and allowed to cool slowly, it is rendered elastic. This is called annealing or tempering steel. (5) It can be magnetized permanently.

(iv) *Uses.*—It is used for making knives, razors, &c.

140. **Green Vitriol** or Ferrous Sulphate ($FeSO_4$).

This is one of the more important salts of iron.

Preparation.—*Expt.* 97.—Dissolve some iron filings in dilute sulphuric acid; the hydrogen of the acid escapes as a gas; while ferrous sulphate or green vitriol is formed. Add some water and filter the liquor. Then boil down, the clear solution and crystals of green vitriol will be formed on cooling.

$$Fe + H_2SO_4 = FeSO_4 + H_2$$

Green vitriol is a pale-green crystalline substance, soluble in water to a great extent. If exposed to air, it is slowly oxidised into ferric sulphate $Fe_2\ (SO_4)_3$ and becomes nearly white. It is largely used in the manufacture of writing ink and in dyeing.

141. **Test for iron Salts.**—*Potassium ferro-cyanide,* $K_4\ Fe\ (CN)_6$, *produces a dark blue (Prussian blue) precipitate with iron salts.*

Expt. 98.—Dissolve a little iron sulphate in water; render the solution slightly acid with a few drops of nitric acid, and then add a few drops of the solution of potassium ferro-cyanide. A Prussian blue precipitate is at once formed.

ALUMINIUM : *Symb. Al.; At. Wt. 27.*

142. **Occurrence.**—Aluminium is not met with in the free state, but occurs in large quantities in many rocks. It is contained in clay and alum.

Preparation.—It is obtained by heating aluminium chloride ($Al\ Cl_3$) with metallic sodium.

$$2AlCl_3 + 3Na_2 = 6NaCl + 2Al.$$

143. **Properties.**—(1) Aluminium is a bright silver-white metal.

(2) It is lighter than most metals in common use, its Sp. Gr. being 2·7.

(3) It does not change in dry or moist air, but when strongly heated in the air, it burns forming alumina, ($Al_2\ O_3$).

Note.—On account of its valuable properties, aluminium is slowly taking the place of copper and brass for making household

144. **Compounds.**—*Alumina* or aluminium oxide, "the earth of clay" (Al_2O_3).

This is prepared by burning aluminium in air. It is a white amorphous powder and is little acted upon by

acids. It is very hard and difficult to melt. The hydrated oxide is very largely used in dyeing and calico-printing, for fixing colours.

Note.—Alumina occurs in nature in the crystalline form as ruby, sapphire and corundum. As emery which is powdered corundum, it is used for polishing metals.

Alums are complex compounds of aluminium sulphate $Al_2(SO_4)_3$ with the sulphates of the alkali metals. Alums are white soluble salts, possessing an astringent taste. They crystallize readily in octahedra and are much used in dyeing and printing cotton cloth.

Felspar (Al_2O_3, K_2O, $6SiO_2$) is a pink coloured crystalline silicate of alumina and potash.

Clay, *porcelain* and *slate* are aluminium silicates.

Test.—*Potassium ferri-cyanide gives a dirty white precipitate with aluminium salts.*

Questions.

* 1. Mention one of the most important ores of iron and state how the metal is obtained from it. In how many different forms is it met with? How do they differ from each other in composition and properties, and for what purposes is each variety used? Mention a liquid which dissolves iron, the substance produced by its action and a test by which the presence of iron in the solution may be recognized.

* 2. What new compound is formed when a piece of iron is dissolved in sulphuric acid, and how would you recognise the presence of the metal in this compound? Calculate the weight o the compound which is obtained by dissolving 10 lbs. of iron in the liquid.

3. Mention the chief ores of iron with their chemical symbols, and give some of the chief properties of pure iron.

4. Give the chief properties of the metal aluminium. Calculate the weight of the compound formed when 200 grammes of aluminium is burnt in air.

* 5. Describe the appearance, composition, a method of preparation, the properties and the uses of green vitriol, alumina and alum.

CHAPTER XX.

CALCIUM : *Symb. Ca.; At. Wt. 40.*

143. **Occurrence.**—Calcium does not exist *free*, but occurs in many familiar compounds such as lime, chalk, gypsum, coral, bone-ash. Calcium is not easily made. When required, it is prepared by decomposing its chloride ($Ca\,Cl_2$) by means of electricity.

146. **Properties.**—(1) Calcium is a light yellow metal which easily oxidizes in air. (2) It acts upon water like potassium and sodium but less energetically. (3) When heated in air, it burns with a bright red light, forming quick-lime.

147. **Compounds.**—(i) *Calcium Chloride* ($CaCl_2$).

Expt. 99.—Dissolve chalk or marble in dilute hydrochloric acid; when, carbon-di-oxide escapes as a gas; calcium chloride remains dissolved in water. Evaporate the solution to dryness.

$$CaCO_3 + 2HCl = CaCl_2 + CO_2 + H_2O.$$

Calcium chloride is a white porous powder which takes up moisture with great eagerness; hence it is used for drying gases. It gives a white precipitate of chalk with a solution of sodium carbonate. It dissolves in sulphuric acid giving off fumes of hydrochloric acid.

$$CaCl_2 + H_2SO_4 = CaSO_4 + 2HCl.$$

(ii) *Calcium carbonate* ($CaCO_3$). This substance occurs in several forms, as chalk, lime-stone, marble, coral and oyster-shells. Its chief crystalline variety is calc-spar, which has the remarkable property of double refraction.

All these forms are insoluble in pure water, but soluble in water containing carbon di-oxide in solution. When heated, they are all decomposed into carbon di-oxide and quick-lime.

$$CaCO_3 = CaO + CO_2$$

Note. — *Chalk* can be precipitated by adding a soluble carbonate to solutions of calcium salts; $CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl$. It is a white, amorphous substance, soft enough to be scratched with the finger-nail. It is used for writing on black-boards.

Limestone is hard and amorphous. It is used in the manufacture of lime and cements.

Marble is white, and appears in minute granular crystals matted together. It is so hard that it can take a high polish. It is used for statues.

(iii) *Lime, quick-lime or calcium oxide* (CaO). This is obtained by heating limestone or sea-shells in kilns with charcoal; when, carbonic acid gas escapes leaving behind lime.

It is a white, amorphous, infusible substance. When heated by the oxy-hydrogen flame, it emits a bright light. It absorbs moisture and carbon-di-oxide from the air. It is, therefore, frequently employed as a drying agent. When a small quantity of water is poured upon it, the mass rapidly becomes hot and steam is given off; while the lime swells up and crumbles to a soft white dry powder called slaked lime. It is also used as manure in marshy lands, for destroying excess of vegetation.

(iv) *Slaked lime* or calcium hydroxide, $Ca(OH)_2$. When we pour just enough of water upon quick-lime for every molecule of lime to combine with a molecule of water, we get slaked lime.

$$CaO + H_2O \quad Ca(OH)_2.$$

Slaked lime is a white amorphous powder sparingly soluble in water. When it is shaken up with water so as to form a white liquid, we have milk of lime which is used to whitewash houses. It absorbs carbonic acid gas readily, forming chalk and water; hence newly built walls remain for a long time damp.

Uses.—It is used chiefly (1) in the preparation of mortar and cements; (2) to loosen the hair on hides, (3) to remove the impurities from coal gas, (4) in the preparation of bleaching powder, ammonia, alkali soda; (5) in the manufacture of glass, and (6) to white-wash buildings and to disinfect.

(v) *Lime-water* is a clear solution of slaked lime in water. It has an alkaline reaction. It is used to test the presence of carbonic acid, to remove temporary hardness in water, and as medicine to help digestion.

(vi) *Gypsum*, Plaster of Paris, or calcium sulphate ($Ca\,SO_4$). It is generally found in nature in the crystalline form. It is precipitated from a solution of calcium chloride by means of sulphuric acid.

$$CaCl_2 + H_2SO_4 \quad CaSO_4 + 2HCl.$$

Gypsum is slightly soluble in water, rendering it permanently hard. When it is heated, it loses its water of crystallization, and forms a fine white powder called Plaster of Paris, which is largely used in making casts, and for plastering the interior of houses. The addition of gypsum to a soil increases its fertility. It is, therefore, used for manure.

(vii) *Bone-earth*, or calcium phosphate, $Ca_3(PO_3)_2$ is obtained when animal bones are calcined in open air. It is a white powder slightly soluble in water. From this is prepared phosphorus. It is a good fertilizer of the soil.

(viii) *Fluor-spar*, or calcium fluoride ($Ca\,F_2$).

MAGNESIUM: *Symb. Mg.; At. Wt. 24.*

148. **Occurrence.**—Magnesium does not exist *free* in nature, but occurs in large quantities in certain minerals and rocks as dolomite ($Mg\,CO_3$), and in sea-water and certain mineral springs as magnesium chloride and sulphate.

Preparation.—It is prepared by treating the chloride ($Mg\,Cl^3$) with sodium at a high temperature.

$$MgCl_2 + Na_2 = Mg + 2\,NaCl.$$

149. **Properties.**—(1) Magnesium is a soft silver-white metal which can be made into wire or ribbon. It has a Sp. Gr. of 1·75.

(2) It does not oxidize in dry air, but is slowly acted upon by cold water but rapidly by warm water.

(3) It is volatile and may be easily distilled at a bright red heat.

(4) When strongly heated in the air, it burns with a dazzling white light and leaves behind some white ashy powder called Magnesia, while black fumes of the unburnt metal and white fumes of the solid oxide escape as soot.

(5) When steam is passed over the heated metal, it is decomposed, magnesia and hydrogen being formed.

(6) It rapidly dissolves in sulphuric acid and hydrochloric acid with evolution of hydrogen.

Uses.—It is used for making fireworks and signals; from its richness in chemically active rays, its light is employed as a substitute for sun-light for photographing the interior of buildings.

150. **Compounds.**—(i) *Magnesia* or magnesium oxide (MgO) is a white amorphous infusible powder obtained by burning a piece of magnesium wire or ribbon in air or oxygen. It has a slightly alkaline reaction, but almost insoluble in water, and unites with acids to form salts. It is largely used in medicine.

(ii) *Epsom salts* or magnesium sulphate ($MgSO_4$). This salt derives its name from the springs at Epsom in England, which contain this salt largely dissolved in them. It is generally obtained by evaporating the spring waters that contain it in solution.

Expt. 100.—Gently heat magnesia, the white ash obtained by burning magnesium in air, with sulphuric acid; the white powder dissolves in the acid forming magnesium sulphate. Then boil down the solution in a dish. On cooling, long needle-shaped white crystals of Epsom salts are obtained.

Magnesia.		Sulphuric acid.		Magnesium Sulphate.		Water.
MgO	+	H_2SO_4	=	$MgSO_4$	+	H_2O.

Epsom salt has a bitter taste and is easily soluble in water. It is used as a mild purgative and for washing wool.

Questions.

1. Give the preparation and the chief properties of calcium and magnesium.

* 2. How is lime obtained from chalk? What weight of the latter is required in order to obtain from it half a ton of the former? By what tests can lime be distinguished from chalk?

Ans. The tests are: (*a*) When hydrochloric acid is poured on chalk, an effervescence of carbonic acid gas is noticed. If poured on lime, carbonic acid gas is not evolved.

(*b*) When chalk is placed in water, it neither dissolves in it, nor does any chemical change take place in it, but when water is poured on lime, much heat is evolved, slaked lime being formed.

* 3. Give the chemical name, the component elements, one method of preparation and uses of the following substances:—Epsom salts, slaked-lime, chalk, quick-lime and bone-ash.

4. Find the weights of calcium chloride and of washing soda necessary to precipitate 60 grammes of chalk.

* 5. How are the following substances prepared, and what are their uses? Lime-water, calcium chloride and magnesia.

* 6. Magnesium is burnt in air and the product dissolved in sulphuric acid. Name all the substances produced, and calculate how much of each would be obtained from 10 grammes of the metal.

7. Complete the equation $CaCO_3 + 2\ HCl =$ and hence deduce the weight of the substances that would be obtained by completely dissolving 40 lbs. of chalk in the acid.

CHAPTER XXI.

THE ALKALI METALS.

SODIUM: *Symb. Na.; At. Wt. 23.*

151. **Occurrence.**—Sodium is never found free in nature but it occurs chiefly as the chloride (NaCl), and

as the nitrate ($NaNO_3$). It is also present in plants growing near, and in, the sea.

Preparation.—It is prepared by taking away the oxygen from soda (Na_2O) by means of electricity. But it is prepared on a large scale by heating a mixture of carbonate of soda (Na_2CO_3) and charcoal in an iron retort. The vapour of sodium which distils over is condensed and made to flow into rock-oil.

$$Na_2CO_3 + 2C = 3CO + Na_2.$$

152. **Properties**.—(1) Sodium is a silver-white metal soft enough to be cut with a knife, and has a Sp. Gr. of 0·97.

(2) It has a great attraction for oxygen, and oxidizes in air; hence it is kept under rock-oil which contains no oxygen.

(3) It decomposes water in the cold, liberating hydrogen as a gas and forming alkali soda.

(4) When heated in air, it first melts at a temperature of 97°C.; then takes fire and burns with a bright yellow flame, white fumes of the oxide (Na_2O) being given off.

(5) It is a strong reducing agent like carbon and hydrogen.

Uses.—It is largely used to extract the metals aluminium and magnesium from their chlorides.

153. **Compounds.**—(i) *Soda* or sodium oxide (Na_2O) is prepared by the slow oxidation of sodium in air, or burning a piece of sodium in dry air. It is an unstable compound, being easily converted into caustic soda by absorbing moisture from the air. It is used in the preparation of glass.

(ii) *Caustic or alkali soda,* sodium hydroxide ($NaOH$). This is obtained (1) by evaporating to dryness the water upon which sodium is thrown, (2) by heating sodium carbonate with slaked lime in a silver or an iron vessel.

$$Na_2CO_3 + Ca(OH)_2 = CaCO_3 + 2NaOH.$$

It is a white solid, soluble in water and is highly alkaline and caustic. It has a strong attraction for water and carbon di-oxide. Hence it is used for drying gases and for absorbing carbon di-oxide. It is also largely used in the manufacture of hard soap.

(iii) *Washing soda*, crystals of soda, or sodium carbonate (Na_2CO_3). It is also improperly called soda. It was formerly obtained from the ashes of sea plants, but it is now obtained by heating a mixture of Glauber's salt, charcoal and chalk.

Glauber's Salt.	Chalk.	Charcoal.	Sodium Carbonate.	Calcium Sulphide.	Carbon Monoxide.

$$Na_2SO_4 + CaCO_3 + 4C = Na_2CO_3 + CaS + 4CO.$$

It is an efflorescent, white, alkaline substance used in softening hard gypsum water, for glass making, soap-making, and bleaching.

(iv) *Common, table, or rock salt*, sodium chloride, ($NaCl$) is obtained (1) from mines as rock salt, and (2) from sea water by evaporation. (3) It is formed when a solution of calcium chloride is mixed with a solution of washing soda.

$$CaCl_2 + Na_2CO_3 = CaCO_3 + 2NaCl.$$

It crystallizes in colourless and transparent cubes. It is used to flavour our food, to prevent decomposition of meat, in the preparation of chlorine and its compounds, and all other sodium salts.

(v) *Glauber's salt* or sodium sulphate (Na_2SO_4) is obtained by heating common salt with sulphuric acid. A dense fume of hydrochloric acid is given off and sodium sulphate is left behind.

$$2NaCl + H_2SO_4 = 2HCl + Na_2SO_4$$

It crystallizes in prisms, and readily parts with its water of crystallization crumbling down to powder. It

is prepared chiefly to be used in the manufacture of sodium carbonate.

(vi) *Chili-saltpetre* or sodium nitrate, ($NaNO_3$). It is found in Peru, and is used in the manufacture of nitric acid and nitre, and as an ingredient in artificial manures. It is very soluble in water. When exposed to the air, the salt absorbs moisture; and on this account, it cannot be employed as a substitute for nitre in the manufacture of gunpowder.

Test for sodium and its salts.—These impart a *golden yellow colour to the flame.*

POTASSIUM : *Symb. K. ; At. Wt. 39.*

154. **Occurrence.** Potassium, like sodium, is never found in the *free* state. It exists combined in felspar and nitre. It is also contained in the substance of most plants.

Preparation.—Potassium is now manufactured by distilling a mixture of potashes and charcoal.

$$K_2CO_3 + 2C = K_2 + 3CO.$$

155. **Properties.**—(1) Potassium is a silver-white metal, soft enough to be cut with a knife and has a Sp. Gr. of 0·8.

(2) It has a strong affinity for oxygen. When exposed to the air, it slowly oxidizes into potash (K_2O). Hence it is kept under rock-oil which has no oxygen.

(3) It decomposes water with great energy even at the ordinary temperature, causing the liberated hydrogen to burn.

(4) When heated, it melts at a temperature of 62°C., and then burns with a *violet* flame forming **potash**.

156. **Compounds.**—(i) *Potash* or **Potassium** oxide (K_2O) is obtained by the oxidation of potassium in dry

air. By exposure to moist air, it is readily converted into alkali potash. It is used in the preparation of flint and Bohemian glass.

(ii) *Alkali or caustic potash*, Potassium hydroxide, (KOH) is obtained by mixing potassium carbonate with slaked lime in a silver or an iron vessel,

$$K_2CO_3 + Ca(OH)_2 = 2KOH + CaCO_3$$

or by evaporating to dryness the water upon which potassium is thrown.

It is a white solid, soluble in water, highly alkaline and powerfully caustic. It has a strong attraction for moisture and carbonic acid gas. It is used for drying gases, and for absorbing carbon di-oxide, and in the manufacture of soft soaps.

(iii) *Potashes* or potassium carbonate (K_2CO_3).

When plants are burnt, the carbonate remains in the ash. If the soluble portion of the ash is dissolved and evaporated, we get potassium carbonate.

It is a very soluble salt which, if exposed to the air, attracts moisture and soon becomes liquid. It is strongly alkaline, and is used in the preparation of glass and other potassium compounds.

(iv) *Nitre*, saltpetre, or potassium nitrate, (KNO_3). This is found in the form of crystals on the soil of tropical countries, such as India.

Preparation.—(1) Refuse matter from stables is exposed in heaps mixed together with wood-ashes and lime to the action of air. The nitrogen contained in the organic matter gets gradually oxidised into nitric acid, and this combining with lime and potash yields nitre which is separated by washing and crystallization.

(2) Nitre is obtained by decomposing Chili-saltpetre with potassium chloride and allowing the products to crystallize.

$$KCl + NaNO_3 = KNO_3 + NaCl.$$

Nitre crystallizes in long rhombic prisms and has a saline taste. It readily dissolves in water. When heated, it parts with a third of the oxygen it contains.

$$2KNO_3 = 2KNO_2 + O_2.$$

It is chiefly used in the preparation of nitric acid, and in the manufacture of gun-powder and fire-works.

Gun-powder is an intimate *mixture* of 1 part of sulphur, 2 parts of nitre, and 3 parts of charcoal. The chemical change that takes place, when gun-powder is exploded, may be roughly represented thus:—

$$S + 2KNO_3 + 3C = 3CO_2 + N_2 + K_2S.$$

When gun-powder is heated, the oxygen of the nitre combines with the charcoal to form carbon di-oxide, and the sulphur with potassium to form potassium sulphide; while nitrogen escapes as gas.

Note.—Gun-powder can also burn in a place devoid of air or under water, as the burning substance, *viz.*, carbon gets the necessary oxygen from nitre of which it contains about 48 per cent.

(v) *Chlorate of potash*, or potassium chlorate ($KClO_3$) is prepared by passing chlorine through warm and concentrated solution of caustic potash. The reaction may be represented thus:

$$3Cl_2 + 6KHO = KClO_3 + 5KCl + 3H_2O.$$

The chlorate is easily separated from the more soluble chloride by crystallization.

It is a crystalline salt sparingly soluble in cold water. When heated, it is decomposed into potassium chloride and oxygen. Hence it is used in the preparation of oxygen. It is also used in the manufacture of lucifer matches and in calico printing, as an oxidizing agent.

Test for Potassium and its salts.—*These salts colour the flame violet.*

157. **Soap.**—Soaps are the alkali salts produced by acids contained in fats. Soap is made by boiling animal or vegetable fats or oils with an alkali.

Expt. 101.—Pour half an ounce of castor oil into a thin porcelain basin with some hot water, and add some caustic soda or potash. On boiling the liquor, the oil will all disappear and soap will be formed dissolved in the water. When it has boiled for some time, throw in a handful of common salt. This will dissolve in the water, and drive out the soap, which will swim on the surface. When cool, this soap will become a white hard solid and may be used for washing purposes.

Soaps containing soda are hard soaps; potash gives soft soaps.

158. **Potassium** and **Sodium compared.**

(i) *Points of similarity.*—1. Both are silver white metals.

2. Both are soft enough to be cut with a knife.

3. Both rapidly tarnish in the air. Hence they are kept in rock-oil.

4. Both decompose water at the ordinary temperature.

5. Both take fire and burn when heated in air.

6. Both are lighter than water and therefore float in it.

7. Both are alkali metals.

8. Both replace the hydrogen of an acid an atom for atom. The two are, therefore, monad elements.

9. Both have similar compounds which are, as a rule, (*a*) white in colour, (*b*) soluble in water, (*c*) alkaline in reaction.

(ii) *Points of dissimilarity.*—(1) Potassium burns in air with a violet flame, but sodium with a golden yellow flame.

(2) Potassium, when thrown on cold water, decomposes it with sufficient energy to cause the ignition of the hydrogen evolved; whereas, in the case of sodium, the action is not sufficiently energetic to effect the inflammation of the gas evolved, unless the water be previously heated.

(3) The atomic weight of potassium is 39; but that of sodium is 23.

(4) Potassium has a Sp. Gr. of 0·8; while sodium has a Sp. Gr. of 0·97.

(5) Potassium melts at a temperature of 52°C; while sodium at 97°C.

(6) Potassium yields soft soaps, but sodium hard soaps.

Questions.

1. Compare and contrast the properties of sodium and potassium.

* 2. How are the following prepared? Give their properties and uses:—Nitre, Glauber's salt, soda, potash, common salt, chlorate of potash, Potashes, and washing soda.

* 3. What takes place when (*a*) saltpetre, (*b*) chlorate of potash, (*c*) sodium, and (*d*) potassium are heated in air?

* 4. (*a*) Charcoal will burn in the air, but if it be placed in the vessel from which air is excluded it will not burn. If, however, some nitre be mixed with the charcoal before it is placed in the vessel, the charcoal can be made to burn in spite of the exclusion of the air. Explain clearly why the charcoal burns in the vessel, when nitre is mixed with it and not before.

(*b*) What important use has been made of this power which nitre possesses of making charcoal burn in spaces destitute of air?

5. Calculate the weight of Chili-saltpetre and of nitre required to produce 5 lbs. of nitric acid.

* 6. What substances are used in making soap? Give some account of the process of its manufacture.

CHAPTER XXII.

COPPER: *Symb. Cu.; At. Wt. 63.*

159. **Occurrence.** Copper occurs *free* in nature near lake Superior and in Chili. But it is more generally got from its ores.

The chief ores are:—

1. Cupric sulphide, Cu_2S.
2. Copper glance, CuS
3. Copper pyrites, $Cu_2S\ Fe_2S_4$.
4. Cupric oxide, CuO.
5. Ruby copper, Cu_2O.

Preparation.—Copper is obtained from the oxide by heating it with charcoal.

$$2Cu_2O + C = 4Cu + CO_2.$$
$$2CuO + C = 2Cu + CO_2.$$

Copper is prepared from the sulphide by roasting it in air; the sulphur separates from the ore as sulphur di-oxide and the metal is left in the form of an oxide, from which pure copper is obtained by reduction.

Pure copper may also be obtained by dipping a piece of clean iron or zinc into a copper solution, or by passing a current of dry hydrogen over heated copper oxide in a glass bulb.

160. **Properties.**—(1) Copper is a tough, hard metal of a reddish colour.

(2) It can be drawn into very fine wire, rolled into foil, and hammered into leaf.

(3) Next to silver, it is the best conductor of heat and electricity.

(4) In dry air, it does not change, but when heated in the air, it becomes black forming copper oxide.

(5) It melts at a red heat and imparts a green colour to the flame.

(6) It readily dissolves in nitric acid forming copper nitrate, but neither sulphuric acid nor hydrochloric acid acts upon it at the ordinary temperature.

Uses.—It is much used for making boilers, vessels, wires, and in many alloys such as brass, bronze, Britannia metal, and German silver.

161. **Alloys**—Alloys are mixtures of metals made by melting them together. They are largely used in the arts, because they are (1) *harder*, (2) *more elastic*, and (3) *more fusible* than the constituent metals.

The chief alloys are:—

1. *Brass*—2 parts of copper and 1 part of zinc.
2. *Britannia metal*—84 parts of tin, 4 of copper, 10 of antimony and 2 of bismuth.
3. *German silver*—Copper, nickel and zinc.
4. *Pewter*—3 parts of tin and 1 of lead.
5. *Solder*—1 part of tin and 1 of lead.
6. *Type metal*—5 of tin, 75 of lead and 20 of antimony.

7. *Bronze*—Copper and tin. There are several varieties :—

(a) Aluminium bronze—90 parts of copper and 10 of aluminium.

(b) Bell-metal—80 parts of copper and 20 of tin.

(c) Gun-metal—90 parts of copper and 10 of tin.

(d) Speculum metal—33 parts of copper and 67 of tin.

(e) Bronze coinage—95 parts of copper, 4 of tin and 1 of zinc.

Note.—Alloys of tin and lead are all white. If an alloy contains over 50 per cent. of zinc, it is white ; if over 80 per cent. of copper it is red or reddish yellow.

162. **Compounds.**—(i) *Black oxide of copper*, or cupric oxide (CuO) is formed, when copper is heated in the air. It is a black powder soluble in acids. It is reduced to the metallic state, if hydrogen is passed over it when red-hot. It is used in ascertaining the composition of water by weight and in the manufacture of green glass.

(ii) *Blue-stone*, blue vitriol, or copper sulphate ($CuSO_4$) is prepared by boiling metallic copper with oil of vitriol diluted with half its bulk of water and evaporating the solution to dryness.

$$Cu + 2H_2SO_4 = CuSO_4 + 2H_2O + SO_2.$$

It crystallizes in beautiful blue prisms. When heated to redness, it loses all its water of crystallization and forms a white powder, but again becomes blue when dissolved in water. It is a powerful caustic used to burn away the fleshy growth in ulcers. It is employed in calico-printing and in the preparation of copper pigments.

(iii) *Copper nitrate*, $Cu(NO_3)_2$ is obtained by dissolving copper in nitric acid and evaporating the solution. It is a crystalline salt soluble in water.

163. **Tests for Copper.**—1. When ammonia is added drop by drop to solutions of copper salts, a greenish blue precipitate is produced. When excess of ammonia is added, the precipitate disappears and a deep blue solution is formed.

2. When the blade of a knife or a piece of zinc is dipped into a solution of copper salts, the copper is precipitated, the iron or zinc being coated with it.

ZINC : *Symb. Zn.*; *At. Wt. 65.*

164. **Occurrence.**—Zinc does not occur free in nature. Its chief ore is blende (ZnS). It occurs also as calamine ($ZnCO_3$).

Preparation.—It is generally prepared by roasting blende at a high temperature. The sulphur becomes converted into sulphur di-oxide and the zinc into zinc oxide.

$$2ZnS + 3O_2 = 2SO_2 + 2ZnO.$$

The oxide is then mixed with charcoal and heated in earthenware retorts. The metal volatalizes by the heat and the vapours are condensed.

$$ZnO + C = Zn + CO.$$

165. **Properties.**—(1) Zinc is a hard bluish white metal, showing crystalline structure, when broken across.

(2) It is brittle at the ordinary temperature, but between 100° C. and 150° C. it may be rolled and hammered with ease; whilst, if heated to 200°C., it becomes again brittle and may be powdered.

(3) It does not tarnish in dry air; but when exposed to moist air, it tarnishes superficially.

(4) When heated to redness in air, it takes fire and burns with a bright bluish white flame, forming zinc oxide.

(5) When pure, it is scarcely attacked by hydrochloric or sulphuric acid, but ordinary commercial zinc is energetically attacked by these acids as well as by nitric acid.

Uses.—Zinc is often used (1) as a substitute for lead in roofing, (2) as the active metal in the voltaic battery, (3) for

coating sheet-iron so as to render it less liable to rust, and (4) for mixing with other metals to form useful alloys, such as brass, German silver, and bronze coinage.

Note.—Galvanized iron is iron coated with a film of zinc by dipping it into a bath of molten zinc.

166. Zinc and Magnesium compared.

i. *Points of similarity.*—(1) Both are white metals.

(2) Both burn when heated in the air.

(3) Both metals, on burning, leave a white oxide.

(4) Both do not tarnish in dry air.

(5) Both decompose water in the state of steam at high temperatures.

(6) Both can be converted into vapour.

(7) The sulphates of both metals are formed by dissolving the metals or their oxides in sulphuric acid.

(8) *An* atom of each metal displaces *two* atoms of hydrogen of an acid to form salts. Both are therefore dyad elements.

$$H_2SO_4 + Zn = ZnSO_4H_2$$
$$H_2SO_4 + Mg = MgSO_4H_2$$

ii. *Points of dissimilarity.*—(1) Magnesium is a *silver* white metal, but zinc is a white metal with a *bluish* tinge.

(2) Magnesium burns in air more easily than zinc.

(3) The light emitted by the metals differs both in colour and intensity; magnesium burns with a bright dazzling white light, zinc with a bluish white light.

(4) The combining weight of magnesium is 24 and that of zinc 65.

(5) Magnesium is lighter than zinc. The former has a Sp. Gr. of 1·7 and the latter a Sp. Gr. of 7.

(6) The process of obtaining magnesium is costly; hence the metal is costly; whereas, zinc is cheap.

(7) The compounds of magnesium are numerous and abundant in nature; but there is only *one* important compound of zinc.

(8) Zinc forms useful alloys with other metals, magnesium does not.

167. Compounds.—(i) *Zinc oxide* (ZnO) is obtained in the form of white powder by burning the metal in a

current of air. It is insoluble in water but dissolves in acids giving rise to the different zinc salts. When heated it becomes yellow, but again becomes white on cooling. It is used as a paint under the name of *zinc white*.

(ii) *White vitriol* or zinc sulphate, ($ZnSO_4$). When zinc is dissolved in dilute sulphuric acid, hydrogen is given off and zinc sulphate is left behind. The solution is then filtered and boiled down. On cooling, white prismatic crystals are formed.

Zinc sulphate is a white substance extremely soluble in water. If swallowed in large quantities, it produces vomiting. It is used in the preparation of certain pigments, and as an emetic in medicine.

Test.—*Potassium Ferri-cyanide produces an orange precipitate with zinc salts on addition of nitric acid.*

TIN: *Symb. Sn.; At. Wt. 118.*

168. **Occurrence.**—Tin does not occur free in nature. The chief ore is tin stone (SnO_2).

Extraction of tin.—Mix some powdered tin-stone with about the same quantity of carbonate of soda, put the mixture in a hole made in a bit of charcoal and heat it in the luminous flame of the spirit lamp. The oxygen, combining with the carbon, escapes as carbonic oxide; while the metal is left as a white globule.

$$SnO_2 + 2C = Sn + 2CO.$$

169. **Properties.**—(1) Tin is a silver-white metal, which does not tarnish in air.

(2) It is rather soft and very malleable so that it is easily beaten out into leaf known as tin-foil; but it is not tough enough to be drawn into wire.

(3) It melts at 230°C. and has a considerable tendency to crystallize.

(4) When strongly heated in air, it takes fire and burns with a white light forming a white amorphous powder called stannic oxide (SnO_2), which is used for polishing glass.

(5) Strong hydrochloric acid dissolves it readily with the evolution of hydrogen, forming the chloride of the metal. Dilute nitric acid oxidizes it violently.

Uses.—Tin is used (1) for plating iron to prevent it from rusting, (2) for silvering mirrors, and (3) as a constituent of many important alloys, as *Pewter*, *Solder*, *Britannia metal*, *Bronze* and *type-metal*.

Note.—The metal tin may be recognised by its leaving the insoluble oxide when treated with nitric acid.

Test.—*Auric chloride ($AuCl_3$) produces a deep Prussian blue precipitate (known as the purple of Cassius) with tin salts.*

LEAD: *Symb. Pb.; At. Wt. 207.*

170. **Occurrence.**—Lead does not occur *free* in nature. Its chief ore is galena (PbS). It is also found in the form of lead carbonate or white lead ($PbCO_3$).

Extraction of lead.—Galena is partially roasted in a furnace whereby a portion of it is converted into lead oxide (PbO) and lead sulphate ($PbSO_4$).

$$\underset{\text{Galena}}{PbS} + \underset{\text{Oxygen}}{2O_2} = \underset{\text{Lead sulphate}}{PbSO_4}$$

$$\underset{\text{Galena}}{2PbS} + \underset{\text{Oxygen}}{3O_2} = \underset{\text{Lead Oxide}}{2PbO} + \underset{\text{Sulphur di-oxide}}{2SO_2}$$

The temperature is then raised without access of air. The oxide and the sulphate react upon a further portion of the sulphide with formation of metallic lead and evolution of sulphur di-oxide.

$$\underset{\text{Lead oxide}}{2PbO} + \underset{\text{Galena}}{PbS} = \underset{\text{Lead}}{3Pb} + \underset{\text{Sulphur di-oxide}}{SO^2}$$

Lead sulphate		Galena		Lead		Sulphur di-oxide
$PbSO_4$	+	PbS	=	$2Pb$	+	$2SO_2$

171. **Properties.**—(1) Lead is a bluish white metal, soft enough to be scratched with the finger-nail.

(2) When freshly cut, it exhibits a bright metallic lustre, but on exposure to *moist* air, its bright surface becomes quickly covered with a film of the oxide which protects the metal from further oxidation.

(3) It leaves a black mark when drawn on paper.

(4) When heated in the air, it melts at 330°C. and when more strongly heated, it is converted into the yellow oxide called litharge.

(5) Nitric acid attacks lead rapidly forming lead nitrate, but sulphuric acid and hydrochloric acid are almost without action upon it in the cold.

Uses.—Lead is extensively used (1) in the construction of cisterns, gutters, and pipes for the storage and distribution of water, (2) for roofing, (3) for making shots and bullets, and (4) in alloys, such as pewter, solder, type-metal, &c.

172. **Tin and lead compared.**

i. *Points of similarity.*—(1) Both are white malleable metals with a bluish tinge.

(2) They easily melt when heated and have a tendency to crystallize.

(3) Both are not tough enough to be drawn into wire.

(4) When heated in air, both are converted into oxides.

(5) Both form useful alloys with other metals.

ii. *Points of dissimilarity.*—(1) Lead leaves a mark when drawn across paper.

(2) The combining weight of lead is 207 and that of tin 118.

(3) When heated in air, lead leaves a yellow oxide, but tin a white oxide.

(4) Lead and its compounds are poisonous.

(5) Lead is a heavy metal having a Sp. Gr. of 11; while tin has a Sp. Gr. of 7.

173. **Compounds.**—(i) *Litharge* or lead mon-oxide (PbO) is formed when lead is strongly heated in the air. It is a yellowish powder which fuses at a full red-heat. It is slightly soluble in water, and the solution is alkaline. It readily dissolves in acids forming the salts of the metal. It is used in making fusible glass.

(ii) *Red-lead* or minium (Pb_3O_4) is obtained by heating litharge to a high temperature in a powerful current of air.

If red-lead is heated to redness, the absorbed oxygen is driven off and litharge is left behind. It is a scarlet, crystalline powder used as a pigment and in the manufacture of flint glass.

(iii) *White lead* or lead carbonate ($PbCO_3$). This is prepared by precipitating lead nitrate by an alkaline carbonate.

$$Pb(NO_3)_2 + K_2CO_3 = PbCO_3 + 2KNO_3.$$

It is almost insoluble in water. It is a heavy amorphous powder used as a white paint, hence the name white lead.

(iv) *Chrome-yellow* or lead chromate, ($PbCrO_4$). This is obtained by mixing a solution of potassium chromate (K_2CrO_4) with a solution of lead nitrate or acetate; chrome yellow is precipitated as a yellow powder; while potassium nitrate or acetate remains in solution. It is an insoluble yellow substance used in oil-painting.

(v) *Sugar of lead* or lead acetate, $Pb(C_2H_3O_2)_2$ is prepared by dissolving litharge in acetic acid (vinegar). It is a white soluble salt much used in calico-printing.

N.B. Black lead is the common name for graphite. It contains no lead whatever. It is pure carbon.

174. **Tests.**—1. The compounds of lead, when reduced in charcoal, yield white malleable globules of lead which leave a mark upon paper when drawn across it.

2 Take a solution of any lead salt and add to it some solution of potassium chromate. A yellow precipitate of lead chromate will be produced.

Questions.

* 1. Give the common name and the composition of the most important ore of each of the following metals:—Copper, zinc, tin, iron and lead. Describe a method by which lead may be obtained from its ore.

* 2. Give the chemical name, one method of preparation, the properties and the uses of ;—litharge, white vitriol, sugar of lead, blue stone, white lead, and chrome yellow.

3. Distinguish between (a) red lead, black lead and white lead; (b) German silver, quick-silver and silver; (c) an alloy and an amalgam

4. Why are alloys largely used in the arts? Name the chief alloys of copper and tin.

* 5. Name the compound of copper which is formed when the metal is acted upon by sulphuric acid, and express the changes which occur by an equation. How and in what form can this compound be obtained from its solution, and by what tests could you recognise the presence of the metal in it?

Calculate the weight of copper required to produce 10 lbs. of the compound in the manner referred to.

6. State what takes place, when

(1) Zinc filings are heated in air.

(2) A piece of zinc is placed in a solution of lead acetate.

(3) Carbon is heated with black oxide of copper.

7. Calculate the weight of copper that can be obtained by the complete reduction of 20 lbs. of cupric oxide.

* 8. What is the name and the composition of the chief ore of tin? How is the metal obtained from the ore and for what purpose is it used?

9. Give the tests for copper, tin and lead.

CHAPTER XXIII.

MERCURY: *Symb. Hg.; At. Wt. 200.*

175. **Occurrence.**—Mercury is met with in the free state in small quantities. It is commonly known as

quick-silver. It is the only liquid metal. The chief ore is Cinnabar (HgS).

Mercury is obtained by roasting the ore (HgS) in a current of air. The sulphur is oxidized and escapes as sulphur dioxide. The vapour of the metal is led into a series of cool chambers where it is condensed.

$$HgS + O_2 = Hg + SO_2$$

176. **Properties.** (1) Mercury is a bright silver-white liquid metal.

(2) It does not tarnish on exposure to the air. If heated to a high temperature, it is slowly converted into the red oxide, which at a higher temperature is again decomposed into its constituent elements.

(3) It is insoluble in hydrochloric acid and in *cold* sulphuric acid, but easily dissolves in chlorine and in nitric acid.

(4) Mercury and its compounds are very poisonous, but taken in small quantities, some of them serve as medicines.

(5) It dissolves all the metals except iron and platinum to form amalgams.

Note. *An amalgam* is a mixture of mercury with any other metal.

Uses.—Mercury is used (1) for constructing thermometers and barometers, (2) for silvering mirrors, (3) for extracting silver and gold from their ores, and (4) for amalgamating zinc plates in the voltaic battery.

177. **Compounds.** *Red oxide of mercury*, or mercuric oxide (HgO) is prepared by submitting mercury to prolonged heating in air.

It is a red crystalline powder which, when strongly heated, turns black and becomes decomposed into oxygen and mercury. Hence it is used for preparing oxygen gas. It is insoluble in water but dissolves in acids.

178. **Test for mercury** and its salts. Drop a bright copper piece into a solution of a mercury salt. The copper will be coated with a film of mercury which will become bright on rubbing.

SILVER: *Symb. Ag.*; *At. Wt. 108.*

179. **Occurrence.**—Silver is occasionally found free. Its chief ore is silver sulphide (Ag_2S).

Extraction.—The ore is roasted with common salt in a furnace; silver chloride ($AgCl$) and sodium sulphide are formed.

$$Ag_2S \ + \ 2NaCl = 2AgCl \quad Na_2S.$$

The silver chloride is shaken up with mercury and scrap-iron, the latter combines with chlorine; while the mercury dissolves silver, forming a liquid amalgam. By distilling mercury off, metallic silver remains behind.

180. **Properties.** (1) Silver is a soft white metal with a high lustre.

(2) It is not acted upon by air, oxygen, or water at the ordinary temperature; but it becomes black when brought near sulphur, a black sulphide being formed.

(3) It is the best conductor of heat and electricity.

(4) Next to gold, it is the most malleable and ductile metal.

(5) It dissolves in dilute nitric acid and boiling sulphuric acid.

Uses.—Silver is used for ornaments, jewels and for coins.

Note.—A little copper is added to silver and gold-coins to make them hard and thus endure wear and tear.

181. **Compounds.**—(i) *Silver nitrate* or lunar caustic ($AgNO_3$) is obtained by dissolving silver in nitric acid and evaporating the solution to dryness.

$$Ag_2 + 4HNO_3 = 2AgNO_3 + 2NO_2 + 2H_2O.$$

Properties.—(1) Silver nitrate is a white crystalline salt which easily dissolves in water. The solution is used to find

the presence of common salt in water, as it forms an insoluble precipitate of silver chloride. (2) It is powerfully caustic and destroys flesh; hence it is used to cauterize wounds. (3) Like other silver salts, it turns black by sunlight, chiefly in the presence of organic matter; hence it is used in photography and for making "indelible inks" to mark linen goods. (4) Copper, zinc, and phosphorus, when placed in a solution of silver nitrate, separate the silver in crystalline plates.

(ii) *Silver chloride* ($AgCl$) is obtained by treating a solution of silver nitrate with common salt or a soluble chloride, and filtering the solution.

It is a white insoluble salt, but it readily dissolves in ammonia. When exposed to sunlight, chiefly in the presence of organic matter, it undergoes partial decomposition, changing its colour. Hence it is used in photography to fix the pictures.

182. Ordinary silver coins contain copper.

Expt. 102.—Cut a bit of a two-anna piece, put it into a test-tube and pour on it some nitric acid. On warming gently, the whole piece will readily dissolve in the acid with the evolution of dense reddish brown fumes of nitric peroxide, and a blue solution of silver nitrate and copper nitrate will be left behind.

Now, add to this a solution of common salt. A dense white precipitate will be thrown down. This shows that the solution contains silver. The chemical change which takes place is expressed by the equations,

$$AgNO_3 + NaCl = AgCl + NaNO_3$$

$$)_2 + \overbrace{2NaCl}^{\text{soluble.}} = \overbrace{2NaNO_3 + CuCl_2}^{\text{Both soluble.}}$$

Filter off the white insoluble silver chloride. The blue solution will contain all the copper. The presence of copper may be shown by dipping a clean blade of a knife into the solution; when, red-metallic copper will be deposited. The presence of copper may also be proved by the ammonia test. 165.)

Note 1.—If the solution is acid, it should be first neutralized by an alkali; otherwise, the blade will simply dissolve in the acid, no copper being deposited.

Note 2.—The silver may be separated from the precipitate of silver chloride by mixing it with sodium carbonate and heating the mixture strongly with the blow-pipe flame in a hole made in a piece of charcoal.

183. **Test for silver** *and its salts.*—Make a solution of a silver salt. To one portion of it, add some solution of common salt; a white curdy precipitate, soluble in ammonia, will be produced. If to another portion we add some potassium chromate solution, a dark red precipitate will be formed.

GOLD: *Symb. Au.; At. Wt. 197.*

184. **Occurrence.**—Gold is always found in the *free* state but enclosed in quartz.

(i) **Properties.**—1. Gold is a heavy metal possessing a brilliant yellow colour and high lustre. In thin films, it transmits green light.

2. It is the most malleable of the metals, and can be drawn out into fine wire.

3. It never tarnishes in air or gets stained with sulphur like silver.

4. It is not acted upon by any single acid (except selenic), but dissolves in the presence of free chlorine and in nitro-hydrochloric acid known as *aqua regia* or royal water.

(ii) *Uses.*—Gold is used for coinage and jewelry. In the form of leaves, it is used for gilding.

185. **Aqua Regia** is a mixture of one part of nitric acid and 3 parts of hydrochloric acid, and is so called because it dissolves gold, the king of metals. *The action of aqua regia* :—Nitric acid liberates chlorine from hydrochloric acid; this chlorine acts upon gold forming gold chloride ($AuCl_3$.)

Questions.

1 Name one of the most important ores of mercury and silver and describe the process of extracting the metals from their ores.

* 2. Give the chief properties of mercury and magnesium.

3. What takes place when :—
   (i) Mercury is heated in air.
   (ii) Silver is left in contact with sulphur
   (iii) A gold-ring is placed in a dish of mercury.
   (iv) Hydrochloric acid is mixed with nitric acid.
   (v) A solution of common salt is added to a solution of silver nitrate.

4. Calculate the weight of the substances formed, (*a*) when 10 grs. of mercury is heated, and (*b*) when the same weight of common salt is added to a solution of silver nitrate.

* 5. How will you show that a two-anna piece contains copper?

6. (*a*) Give the chief properties of silver and gold.
   (*b*) Of what use is the copper in silver and gold coins?
   (*c*) What great advantage has gold over silver in its use as an ornament?

* 7. How are the following substances prepared? Red oxide of mercury, chloride of silver, and lunar caustic. Give their chief properties and uses.

* 8. Silver chloride is an insoluble and cupric chloride a soluble salt. Explain clearly how, taking advantage of the above facts, the silver could be separated from the copper in a solution containing silver and cupric nitrates.

Supposing you had succeeded in separating the silver from the copper, how would you proceed to test for copper

9. What is aqua regia? Explain its action upon gold.

CHAPTER XXIV.

GENERAL FACTS.

186. **The elements that are found in the free state :**

Non-metals.	Metals.
(1) Oxygen.	(1) Gold.
(2) Nitrogen.	(2) Silver.
(3) Carbon.	(3) Mercury.
(4) Sulphur.	(4) Copper.
	(5) Platinum.
	(6) Iron (very rarely).

Note.—Gold occurs only in the free state.

187. Elements that oxidize.—(i) *By mere exposure to air*, (or by heat):

Names of the elements.		Names of the oxides and their symbols.
(1) Phosphorus	...	Phosphorus anhydride (P_2O_3) Phosphoric anhydride (P_2O_5)
(2) Potassium	...	Potash (K_2O).
(3) Sodium	...	Soda (Na_2O).
(4) Calcium	...	Quick-lime (CaO).
(5) Iron	...	Iron oxide (FeO).
(ii) *When heated* (only):		
(1) Sulphur	...	Sulphur di-oxide (SO_2).
(2) Carbon	...	Carbon di-oxide CO_2).
(3) Silicon	...	Silica (SiO_2).
(4) Aluminium	...	Alumina (Al_2O_3).
(5) Magnesium	...	Magnesia (MgO).
(6) Copper	...	Cupric oxide (CuO).
(7) Tin	...	Tin oxide (SnO_2).
(8) Zinc	...	Zinc oxide (ZnO).
(9) Lead	...	Litharge (PbO).
(10) Mercury	...	Mercuric oxide (HgO).

188. Metals which do not tarnish in air.

Gold,	Mercury,	Tin,
Silver,	Aluminium,	Zinc,
Platinum,	Magnesium,	Lead.

189. Occurrence of metals.—(i) Metals whose ores are *sulphides*.

Metal.	Ore.	Symbol.
Iron	Iron Pyrites	FeS_2.
Lead	Galena	PbS.
Zinc	Blende	ZnS.
Mercury	Cinnabar	HgS.
Copper	Copper glance Cupric sulphide Copper pyrites	CuS. Cu_2S. $Cu_2S + Fe_2S_3$
Silver	Silver sulphide	Ag_2S.

(ii) Metals whose ores are *oxides*:

Iron	Red Hæmatite	Fe_2O_3.
	Lode-stone	Fe_3O_4.
Tin	Tin-stone	SnO_2.
Copper	Ruby copper	Cu_2O.
	Cupric oxide	CuO.

190. **Properties of metals.**—(i) *The properties which distinguish metals from non-metals.*

(1) Metals have the power to replace the hydrogen of acids and form salts.

(2) They have a shining surface known as the metallic lustre.

(3) They are opaque.

(4) They are good conductors of heat and electricity.

(5) They all appear at the negative pole in the electrolysis.

(6) They do not form compounds among themselves.

(7) They are generally malleable and ductile.

Note.—Silver is the best conductor of heat and electricity; gold is the most malleable metal, and platinum the most ductile metal.

(ii) *Metals that can be volatalized*:—Mercury, zinc, magnesium, potassium and sodium.

(iii) *Colour.*—*White*:—Silver, platinum, aluminium, iron, mercury, tin, magnesium, potassium, and sodium. *Red*:—Copper. *Yellow*: Gold and calcium. *Bluish*:—Zinc and lead.

(iv) *Metals which can take crystalline form*:—Zinc, tin, lead, and copper.

191. **Elements** *that have allotropic forms.*

1. Oxygen:—Oxygen and ozone.
2. Carbon:—Diamond; Graphite; Coal, better charcoal.
3. Sulphur:—Octahedral; Prismatic; Plastic; White amorphous.
4. Phosphorus:—Yellow and Red.

5. Silicon :—Crystalline ; Amorphous.

192. (i) *Reducing agents* :—Carbon, hydrogen, sodium, sulphur di-oxide.

(ii) *Oxidizing agents* :—Nitric acid, ozone, nitre, potassium chlorate.

(iii) *Efflorescent salts* :—Green vitriol, blue vitriol, washing soda.

(iv) *Deliquescent salts* :—Potassium carbonate, calcium chloride, ammonium carbonate.

(v) Gases that can be prepared by *upward displacement* : Hydrogen, coal gas, ammonia.

(vi) Gases that are prepared by *downward displacement* : Carbon di-oxide, chlorine, hydrochloric acid gas.

(vii) *Bleaching agents* : Chlorine, sulphur di-oxide, ozone.

(viii) *Drying agents* : Sulphuric acid, quick-lime, caustic potash, calcium chloride.

(ix) Some *crystalline minerals* produced in the earth by crystallization, felspar, heavy-spar, fluor-spar, calc-spar, quartz.

(x) *Alkalies* :—Ammonia, caustic potash, caustic soda.

193 Chemical conduct of Sulphuric acid.

(1) *Action on metals.*—When Sulphuric acid acts upon a metal, hydrogen gas is evolved and the Sulphate of the metal is formed.

$$Zn + H_2SO_4 = H_2 + ZnSO_4$$
$$Mg + H_2SO_4 = H_2 + MgSO_4$$
$$Fe + H_2SO_4 = H_2 + FeSO_4$$

Note.—When the acid acts upon copper, mercury, sulphur or carbon, sulphur di-oxide is evolved.

$$S + 2H_2SO_4 = 2H_2O + 3SO_2$$
$$Cu + 2H_2SO_4 = SO_2 + CuSO_4 + 2H_2O$$
$$C + 2H_2SO_4 = 2SO_2 + CO_2 + 2H_2O$$

(2) *Action on oxides.*—When the acid acts upon oxides, the hydrogen of the acid unites with the oxygen of the oxide to form water, and the sulphate of the metal is left.

$$MgO + H_2SO_4 = MgSO_4 + H_2O$$
$$ZnO + H_2SO_4 = ZnSO_4 + H_2O$$
$$CaO + H_2SO_4 = CaSO_4 + H_2O$$

(3) *Action on alkalis.* The acid neutralizes the alkali with the formation of water and a sulphate.

$$2KOH + H_2SO_4 = K_2SO_4 + 2H_2O$$
$$2NaOH + H_2SO_4 = Na_2SO_4 + 2H_2O$$

(4) *Action on carbonates.*—When the acid acts upon carbonates, carbon di-oxide is evolved and the sulphate of the metal is formed.

$$K_2CO_3 + H_2SO_4 = CO_2 + K_2SO_4 + H_2O$$
$$CaCO_3 + H_2SO_4 = CO_2 + CaSO_4 + H_2O$$
$$Na_2CO_3 + H_2SO_4 = CO_2 + Na_2SO_4 + H_2O$$

(5) *Action on nitrates.*—When the acid acts upon nitrates, nitric acid vapours are formed.

$$KNO_3 + H_2SO_4 = HNO_3 + KHSO_4$$
$$NaNO_3 + H_2SO_4 = HNO_3 + NaHSO_4$$

(6) *Action on sulphides.* Hydrogen sulphide is evolved and the sulphate of the metal is formed.

$$FeS + H_2SO_4 = FeSO_4 + H_2S$$
$$CuS + H_2SO_4 = CuSO_4 + H_2S$$

(7) *Action on chlorides.*—Hydrochloric acid gas is evolved; while the sulphate of the metal is left.

$$CaCl_2 + H_2SO_4 = CaSO_4 + 2HCl$$
$$2NaCl + H_2SO_4 = Na_2SO_4 + 2HCl$$

194. Soluble and Insoluble Salts of the same Metal.

Metals.	*Soluble Salts.*	*Insoluble Salts.*
Calcium.	(1) Quick-lime.	(1) Chalk.
	(2) Gypsum.	(2) Bone-earth.
	(3) Calcium chloride.	(3) Fluor-spar.
Lead.	(1) Sugar of lead.	(1) Chrome yellow.
	(2) Lead nitrate.	(2) White lead.
Magnesium.	Epsom Salts.	Magnesium carbonates.

195. Colour of the oxides:

White.	*Red.*	*Black.*	*Yellow.*
Potash.	Mercuric oxide.	Cupric oxide.	Iron rust.
Soda.	Cuprous oxide.	Manganese.	Litharge.
Magnesia.	Red lead.	Dioxide.	
Alumina.	Red Hæmatite.	Lodestone.	
Quick-lime.			
Zinc oxide.			
Tinstone.			

196. **Action of metals on water.**—(i) Metals which decompose water at *all temperatures:* Potassium, sodium, and calcium.

(ii) Metals which decompose water *at high temperatures:* Zinc, magnesium, aluminium, iron and tin.

(iii) Metals which decompose water *with the help of an acid*: Zinc, iron, aluminium and magnesium.

(iv) Metals which do *not* decompose water *under any circumstances*: Copper, gold, silver, mercury and platinum.

197. **Alloys:**—*Red* or *yellow.*—Brass and bronze. *Grey* or *white.*—Pewter, Solder, Britannia metal, German silver, and type-metal.

198. **A method of finding the combining weights of elements.**—Each of the numbers representing the combining weights of elements has been found out by experiment, that is, by the analysis of their compounds; thus, when several compounds of oxygen are analysed, the smallest proportion of oxygen in any of these com-

pounds is taken as the combining weight of oxygen, *e. g.*, when red oxide of mercury is analysed, we find that for every 216 parts by weight of the oxide, there are 200 parts of mercury and 16 of oxygen. In carbon di-oxide for every 44 parts by weight of the compound we have 32 of oxygen and 12 of carbon; in chalk for every 100 parts, we have 48 parts of oxygen and so on. 16 being the smallest number denoting the proportion in which oxygen enters into chemical combination with a unit proportion of any other element, this number is taken as the combining weight of oxygen. So for other elements.

Questions.

I.

• 1. Classify the following substances into elementary and compound bodies:—Carbonic acid, chlorine, chalk, chlorate of potash, rock-salt, silicon, charcoal, saltpetre, ammonia, sodium galena, quartz, bone-ash, silica. Mention the elements of which the compounds consist.

• 2. Classify the following substances under the heads (1) elements, (2) chemical compounds, or (3) mechanical mixtures, and in each case give the reasons for your classification —Coal-gas, sea-water, brim-stone, brass, white-lead, quick silver, black-lead quick-lime, gun-powder.

• 3. Name the most important non-metallic elements which are met with in nature in the combined state only, also the most common compounds in which they occur Mention some of the properties of each of these elements and state how any two of them may be obtained from the compounds which you name.

• 4 Name the important metallic elements indicating which do, and which do not occur in the free state. Mention what you consider to be the most important compound of each element, and state anything of importance which you know concerning the compound selected.

• 5. Name 5 elements which undergo chemical changes by exposure to the air at ordinary or at high temperatures. Describe briefly all the phenomena which accompany these changes and name the products.

* 6. The metallic or non-metallic nature of certain elements can be recognized, you are told, by their appearance. What are the properties referred to, and how does a knowledge of them enable you to decide whether an element is a metal or a non-metal?

* 7. Name the compounds formed and state what you *see* when the following elements are heated in air or oxygen:—Magnesium, Sulphur, Carbon, Sodium, Copper, Phosphorus and Zinc. Do the compounds thus produced exhibit any points of resemblance or difference? If so, name them.

Ans. (1) The oxides of carbon, sulphur, sodium, and phosphorus are soluble in water, that of magnesium is sparingly soluble; while those of copper and zinc are insoluble.

(2) The oxides of carbon, sulphur and phosphorus are acid forming ones. Hence they turn blue litmus paper red when dissolved in water; that of magnesium is slightly alkaline, that of sodium, strongly alkaline, while those of zinc and copper are neutral.

(3) The oxides of the 3 non-metals are gases, while those of the others are solids.

(4) The oxide of carbon is colourless, that of copper is black while those of the other elements are white.

(5) The oxides of sulphur and phosphorus possess a smell: and the oxides of carbon and other elements have no smell.

* 8. † Eight gases are shown to you, *viz.*, oxygen, nitrogen, chlorine, carbon monoxide, carbon di-oxide, ammonia, and sulphuretted hydrogen. State the following particulars concerning each of them, (*a*) Its colour. (*b*) Its smell. (*c*) Will it allow a candle to burn in it? (*d*) Will it take fire on application of a flame, and (*e*) if you were making it, would you try and collect it over water?

* 9. What chemical changes take place when the following substances are heated? Chlorate of potash, chalk, gun-powder, red oxide of mercury, sulphur, phosphorus and a mixture of salt-petre and sulphuric acid.

* 10. From what materials are the following substances prepared?—Nitric acid, phosphorus, lime, plate glass, flint glass, chlorine, salt-petre and silver chloride.

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† This question should be answered as follows, assuming that Marsh gas had been asked:—Marsh gas, (*a*) Colourless, (*b*) No smell, (*c*) No, (*d*) Yes, (*e*) Yes.

* 11. Give the composition of the following substances: nitre, slaked lime, diamond, bone ash, glass, red-lead, black lead, solder, fel-spar, ruby, spirits of hart-shorn, laughing gas, and rock-crystal.

* 12. Five glass cylinders are given you containing respectively oxygen, hydrogen, nitrogen, carbonic acid and chlorine. How would you identify the different gases?

13. Calculate the weight of zinc and sulphuric acid required to produce hydrogen sufficient for the complete reduction of 30 lbs of cupric oxide.

* 14 What is meant by saying that the combining weight of oxygen is 16? How has this number been determined?

* 15. How can you show the presence of (1) carbon in sugar, (2) chlorine in common salt, (3) silver in lunar caustic, (4) copper in blue stone, (5) sulphur in gun-powder, (6) lead in litharge?

16. The following substances are given you. What substances could you prepare from them? Common salt, oil of vitriol, lunar caustic, zinc and chalk. Give equations representing the chemical change.

17. What precautions should be taken in the preparation of Chlorine, hydrogen, potassium, caustic soda and phosphorus?

II.

1. Two samples of water are given to you; one is a hard water, and the other is distilled water. Describe two methods of distinguishing between them.

2. Ammonia is classed as an alkali: why? Name some of the sources from which it can be obtained, and give its composition.

3. What names are given to the compounds which metals form with oxygen, with chlorine, and with sulphur respectively. Give two examples of each, and describe their appearance and characteristic properties.

4. State the chief properties of the gas which is evolved when copper is heated with sulphuric acid. Crystallized sulphate of copper was shown to you; describe its appearance. Metallic copper is easily separated from the aqueous solution of the salt; how?

5. Name four of the gases most soluble in water; what happens when solutions of these gases are heated.

6. Of what substances is the air composed? How do you know that the gases present are merely mixed together and are not combined in the form of a chemical compound?

7. Draw the apparatus you have seen used in making chlorine: name the materials required and show how they are used. Describe what is seen when phosphorus, turpentine and heated sodium are put into chlorine gas, and name the substances which are formed in each case.

8. Name and describe the properties of the metals which may be obtained from (*a*) clay, (*b*) soda.

9. What substances are formed when potash and lime are added to separate portions of hydrochloric acid and when nitric acid is poured upon a two-anna piece?

10. What occurs when nitre is placed in water? If the liquid is heated and more nitre added, what happens then? If now the liquid is poured off from any solid nitre that may remain and is allowed to cool, what is the result?

11. Describe the apparatus for making pure drinkable water from sea-water.

12 What is iron-rust? How is it formed? A piece of iron is put into dilute hydrochloric acid. What happens?

13. How may soap be prepared? What is the difference in chemical composition between "hard" and "soft" soap? Describe the action of soap on hard water.

14. State the characters or simple tests by which you would recognise the products of burning carbon, phosphorus, sulphur, and iron in oxygen gas.

15. What is meant by saying that a solution is saturated? How would you prove that no loss of weight occurs when a substance is dissolved in water?

16. What is the composition of lime-stone? Name other substances of the same composition. Explain what occurs when lime-stone (1) is strongly heated; (2) is placed in dilute hydrochloric acid.

17. Describe with a sketch any method of showing that burnt hydrogen is water.

18. You have been told that nitric and hydrochloric acids have the properties belonging to acid in general; what are these general properties?

19. What is the composition of the two principal ores of iron? By what process is the metal extracted from these ores? Name the chief modifications of iron occurring in Commerce. How do they differ?

APPENDIX B.—

Name.	Colour.	Smell.	Sp. Gr. (Air=1)	Whether soluble.
Oxygen ...	Colourless	No smell.	1·105	Slightly ...
Hydrogen ...	do. ...	do. ...	0·069	Very slightly ...
Steam ...	do. ...	do. ...	0·622	Considerably ...
Nitrogen ...	do. ...	do. ...	0·972	Very slightly ...
Ammonia (NH_3)...	do. ...	Pungent...	0·589	Extremely ...
Carbon di-oxide (CO_2).	do. ...	Pleasantly pungent.	1·52	Moderately ...
Carbon mon-oxide (CO).	do. ...	Faint ...	0·97	Slightly ...
Coal-gas ...	do. ...	Strong ...	0·125	do. ...
Chlorine ...	Greenish yellow.	Strong suffocating.	2·45	Considerably ...
Hydrochloric acid gas (HCl).	Colourless	Pungent.	1·25	Extremely ...
Sulphur di-oxide (SO_2).	do. ...	Suffocating.	2·2	do. ...
Sulphuretted hydrogen (H_2S).	do. ...	Offensive.	1·2	Moderately ...
Marsh gas (CH_4)...	do. ...	No smell.	0·55	Very slightly ...
Nitrous oxide (N_2O)	do. ...	do. ...	1·52	Somewhat ...
Nitric peroxide (N_2O_4).	Reddish brown.	Suffocating.	1·55	Slightly ...

A Table of Gases.

Will it allow a lighted candle to burn in it?	Will it take fire on application of flame.	How collected.	Tests.
Yes; brilliantly.	No ..	Over water ..	Rekindles a red-hot splinter of wood.
No	Yes; pale blue flame.	Over water, or by upward displacement.	Burns with a pale blue flame, forming water only.
No .	No ..	By upward displacement.	Is easily condensed into water by cold.
No .	No .	Over water ..	A taper put out, lime-water not turned milky.
No ...	No ..	By upward displacement or over mercury.	Turns moist red litmus paper blue.
No .	No .	By downward displacement.	Turns lime-water milky.
No ...	Yes, pale blue flame..	Over water ...	Smell and the pale blue colour of flame.
No ...	Yes, bright flame.	do. ...	Smell and the luminous flame.
Yes, lurid smoky flame.	No ...	By downward displacement.	Colour, smell, sparks of fire with antimony powder
No ...	No ..	By downward displacement.	Fumes strongly in the presence of NH_3 solution
No ..	No ..	do.	Smell of lucifer matches ignited.
No ...	Yes ...	Over mercury or warm water.	Smell of rotten eggs.
No ...	Yes, pale	Over water ...	......
Yes; brilliantly.	No ..	Over warm water	Sweetish taste.
No ..	No ..	By downward displacement.	The reddish brown colour.

APPENDIX C.—

Common Name.	Chemical Name.	Chemical formula.
Felspar ...	Silicate of aluminium and potash.	$6\ Si\ O_2$.
Flint ...	Silicon di-oxide ...	$Si\ O_2$
Fluor-Spar ...	Calcium fluoride ...	$Ca\ F_2$
Galena ..	Lead sulphide ..	$Pb\ S$
Glauber's salts ...	Sodium sulphate ...	$Na_2\ SO_4$
Green vitriol ...	Ferrous sulphate	$Fe\ SO_4$
Gypsum ...	Calcium sulphate	$Ca\ SO_4$
Heavy spar ..	Barium sulphate ..	$Ba\ SO_4$
Ice ...	Hydrogen monoxide .	$H_2\ O$
Iron rust ...	Ferrous oxide ...	$Fe\ O$
Iron pyrites ...	Ferric sulphide ...	$Fe\ S_2$
Iron sulphide ...	Ferrous sulphide ...	$Fe\ S$
Lead nitrate ...	Plumbic nitrate ..	$Pb\ (NO_3)$
Lime or quick-lime ...	Calcium oxide ...	$Ca\ O$
Lime-stone ...	Calcium carbonate .	$Ca\ CO_3$
Litharge .	Lead monoxide ..	$Pb\ O$
Lodestone or magnetic oxide of iron.	Peroxide of iron ..	$Fe_3\ O_4$
Lunar caustic .	Silver Nitrate ...	$Ag\ NO_3$
Magnesia ...	Magnesium oxide ...	$Mg\ O$
Marble ...	Calcium carbonate ...	$Ca\ CO_3$
Nitre or saltpetre ...	Potassium nitrate ..	$K\ NO_3$
Plaster of Paris ...	Calcium sulphate ...	$Ca\ SO_4$

A TABLE OF SOLIDS—*continued.*

Colour.	Whether soluble in water.	Crystalline or Amorphous.	Preparation, properties, uses, &c.
Pinkish ...	No	Crystalline : rhombic prism ...	p. 109.
Dark, dull looking.	No	Amorphous ...	p. 96.
Colourless, green or purple.	No ...	Crystalline : cubical shape .	p. 138.
Greyish white.	No ..	Crystalline : cubical shape ..	p. 127.
Colourless	.	Crystalline prismatic ...	p. 116.
Pale green	Yes .	Crystalline : monosymmetric	p. 107.
White	Sparingly	Amorphous ...	p. 112.
do ..	No	Crystalline : rhombic form ...	p. 128.
White opaque.	Yes	Crystalline .	p. 42.
Brown	No ...	Amorphous powder ...	p. 105.
Brass yellow	No ..	Crystalline : cubical form ...	p. 105.
Dark yellowish grey	No .	Amorphous ...	p. 91.
White ..	Yes	Crystalline ...	p. 129.
do. ...	Sparingly.	Amorphous	p. 111.
do. ...	No ..	Mostly amorphous ...	p. 110.
Yellowish ...	No .	Crystalline powder ..	p. 129.
Black ...	No	Hard, amorphous	p. 105.
White ...	Yes .	Crystalline : rhombic ...	p. 132.
do. .	Sparingly.	Amorphous powder	p. 118.
do. ..	No ...	Crystalline and granular ...	p. 111.
do. ...	Yes ...	Crystalline : rhombic prism ..	p. 118.
do. ...	Sparingly.	Amorphous ...	p. 112.

APPENDIX C.—

Common Name.	Chemical Name.	Chemical formula.
Potash ...	Potassium oxide ..	$K_2 O$
Potashes ...	Potassium carbonate ...	$K_2 CO_3$
Potassium Ferro cyanide.	......	$K_2 Fe (CN)_6$
Quartz or Rock crystal.	Silica or silicon di-oxide.	$Si O_2$
Red Hæmatite ..	Ferric oxide ...	$Fe_2 O_3$
Red lead ...	Per-oxide of lead ...	$Pb_3 O_4$
Red oxide of mercury	Mercuric oxide .	$Hg O$
Rock-salt ...	Sodium chloride ..	$Na Cl$
Ruby ...	Aluminium oxide ...	$Al_2 O_3$
Ruby copper ...	Cuprous oxide ...	$Cu_2 O$
Sal-ammoniac ...	Ammonium chloride ...	$NH_4 Cl$
Sand or silica ...	Silicon di-oxide ...	$Si O_2$ ...
Sapphire ...	Aluminium oxide ...	$Al_2 O_3$ ...
Silver chloride ...	Argentic chloride ...	$Ag Cl$ ...
Slaked lime ...	Calcium hydroxide ..	$Ca (OH)_2$ ...
Slate ...	Aluminium silicate ...	$Al_2 O_3, 2 Si O_2$ ...
Soda ...	Sodium oxide ...	$Na_2 O$ ...
Soda, caustic or alkali	Sodium hydroxide ...	$Na OH$ ...
Spathic iron ore ...	Ferrous carbonate ...	$Fe CO_3$ ...
Specular iron ore ...	Ferric oxide .	$Fe_2 O_3$ ...
Sugar of lead ...	Lead acetate ...	$Pb (C_2 H_3 O_2)_2$.
Sulphur, Brimstone ..	Sulphur ...	S ...
Tin-stone ...	Stannic oxide ...	$Sn O_2$ ...
White lead ...	Lead carbonate ...	$Pb CO_3$.
Washing soda ...	Sodium carbonate ...	$Na_2 CO_3$ ...
White vitriol ...	Zinc sulphate ...	$Zn SO_4$ ...
Zinc white ...	Zinc oxide ...	$Zn O$ ...

N.B.—(1) The salts of potassium, sodium, magnesium and calcium are, as a rule, white.

A TABLE OF SOLIDS—*continued.*

Colour.	Whether soluble in water.	Crystalline or Amorphous	Preparation, properties uses, &c.
White	Yes	Amorphous	p. 117.
do.	Yes	Crystalline: prismatic	p. 118.
Yellow	Yes	......	p. 108.
Colourless	No	Crystalline: hexagonal prismatic	p. 96.
Red	No	Amorphous	p. 105.
Scarlet	No	Crystalline, powder	p. 129.
Red	No	do.	p. 131.
White	Yes	Crystalline: cubical	p. 116
Red	No	Crystalline	p. 109.
Red	No	Amorphous	p. 121.
White	Yes	Crystalline octahedral and tree-like.	p. 72.
do.	No	Mostly crystalline	p. 96
Blue	No	Crystalline	p. 109.
White	No	Amorphous	p. 133.
do.	Sparingly.	Amorphous powder	p. 111.
Blackish	No	Hard, amorphous solid showing cleavage.	p. 109.
White	Yes	Amorphous powder	p. 115.
do.	Yes	Hard, porous, amorphous	p. 116
Black	No	Amorphous	p. 105
do.	No	Crystalline, hexagonal	p. 105.
White	Yes	Amorphous	p. 129
Yellow	No	Both crystalline and amorphous	p. 89.
White	No	do.	p. 126.
do.	No	Crystalline powder	p. 129.
White, transparent.	Yes	Crystalline: monosymmetric	p. 116.
White	Yes	Crystalline: rhombic prisms	p. 126.
do.	No.	Amorphous	p. 126.

(2) The salts of potassium and sodium are soluble in water.

APPENDIX D.

MADRAS UNIVERSITY QUESTIONS.

DECEMBER 1898.

I. You have given you six glass cylinders, each of which contains one of the following gases:—oxygen, air, hydrogen, nitrogen, hydrochloric acid, carbon dioxide. How would you identify each gas?

II. Describe the appearance and state what you know concerning the composition and properties of the following substances:—washing soda, gypsum, Glauber's salts, oil of vitriol, graphite, galena, marble, alum litharge, sugar of lead.

III. How do the properties of pure air differ from those of its components, and the properties of steam from those of its components? How do you account for the difference?

IV. You have given you a powder consisting of charcoal and saltpetre. How would you separate the two substances from the mixture, and obtain both in the pure state? What would be the result of heating the powder?

V. Make a sketch, occupying a whole sheet of your answer paper, of the apparatus you have seen used to prove the composition of water by passing dry hydrogen over heated copper oxide, and describe how the operation is performed.

From the following results of an expesiment. calculate the percentage composition of water by weight:—

Weight of tube and copper oxide, before the experiment	67·42	grms.
Weight of tube and copper, after the experiment	66·82	,,
Weight of tube for absorbing the water formed, before experiment	55·50	,,
Weight of same tube, after experiment ...	56·176	,,

VI. Describe the appearance and properties of magnesium and of the ash formed when the metal is burnt in air. Is the magnesium contained in the ash or the ash in the magnesium? Give reasons for your answer.

VII. Write an equation for the change which takes place when a mixture of potassium chlorate and carbon is heated, and calculate the weight of the chlorate required to oxidise 10 grammes of carbon to carbon dioxide.

K : Cl : C : O = 39 : 35·5 : 12 : 16.

FEBRUARY 1899

(RE-EXAMINATION).

I. Mention the common metals and alloys you have seen which are white, or nearly white, in colour. In the case of the metals, describe any simple tests by which they can be distinguished from each other.

II. The following experiments are performed:—(1) a piece of phosphorus is burnt in a bell-jar containing air, placed in a shallow vessel full of water, and after the combustion is finished the apparatus is allowed to stand for some time; (2) a piece of sodium is placed on the surface of hot water contained in a vessel. Describe accurately what is observed to take place, and what properties have been acquired by the water, in each case.

III. Nitric acid is an oxidising agent. Describe any experiment you have seen performed which illustrates its oxidising action. How would you prepare the acid from saltpetre? Write an equation for the chemical change by which it is produced.

IV. Red oxide of mercury is heated (1) alone, (2) with carbon, (3) with hydrogen. What products are formed, and what weight of each would be obtained from 10 grammes of the oxide?

V. You are provided with some sulphuric acid, copper, zinc, and marble: what gases can you prepare from these materials? Describe the properties of the gases, and state how they can be distinguished from each other.

VI. Describe what you have seen to take place when a burning candle is brought into jars containing the following gases;—nitrogen, oxygen, hydrogen, chlorine, carbon dioxide. Explain the cause of the effects observed in each case.

H : C : O : Hg = 1 : 12 : 16 : 200.

DECEMBER 1899.

I. (1) What is lime-water, and how is it made?

(2) What chemical and physical changes take place when carbon di-oxide is passed through lime-water for some time?

(3) To a specimen of water, lime-water and caustic potash are separately added, and both produce a white precipitate. With another specimen, lime-water gives the precipitate, but caustic potash does not. What inferences may be drawn from these observations regarding the substances present in each sample of water?

Ans. (1) Hard chalk water, (2) Water containing carbon dioxide in solution. § 62.

II. State, without giving experimental details:—

(1) how the volume and the weight of oxygen which combines with unit volume and weight of hydrogen to form water can be ascertained;

(2) how, from these numbers, the relative densities of the two gases may be calculated.

III. (1) Mention all the substances produced when common salt, manganese di-oxide, and sulphuric acid are mixed.

(2) Account for the fact that chlorine is evolved when sulphuric acid is added to a mixture of the other two substances, whereas, when it is added to each separately, no chlorine is evolved.

IV. You are required to prepare, and to collect by displacement of air, a glass cylinder full of hydrogen and another of carbon di-oxide Make sketches, each drawing occupying one sheet of your answer paper, of the apparatus you would employ in preparing each gas.

V. Explain why, when phosphorus is burnt in a vessel containing air inverted over water, both the volume and the weight of the air are greatly diminished; but when charcoal is burnt, the volume is only slightly diminished and the weight is increased.

Ans. White fumes of Phosphoric Anhydride take the place of the oxygen in air. The fumes completely dissolve in the

water and in consequence the volume and the weight of the air are greatly diminished. In the second case, carbonic acid gas takes the place of the oxygen. But it is only slightly soluble in water. Hence the volume is only slightly diminished. A given volume of carbon di-oxide weighs 1¼ times as much as the same volume of oxygen. Hence the weight of air after combustion is increased.

VI. Calculate the weight in grammes of zinc which must be dissolved in sulphuric acid in order to obtain sufficient hydrogen to yield on burning 10 grammes of water.

VII. A compound has the following percentage composition :—

Potassium	=	28·7
Hydrogen	=	0·8
Sulphur	=	23·5
Oxygen	=	47·0
		100·0

What is its formula and name ?

H : O : K : S : Zn = 1 : 16 : 39 : 32 : 65.

MARCH 1899.

(RE-EXAMINATION.)

I. Describe any experiments *you have seen performed* which prove :—

(1) that the proportion of carbonic acid in ordinary air is very small ;

(2) that the proportion in expired air is much larger ;

(3) that plants decompose carbonic acid and liberate the oxygen it contains.

II. (1) Distinguish between the " burning of coal " and the " distillation of coal."

(2) Enumerate the substances which are given off and left behind in each case, and state of what they

III. (1) Make a sketch of a candle flame, not less than actual size.

(2) Describe the appearance of each part of region of the flame.

(3) State what is taking place in each part of the flame.

(4) By what experiments can it be shown that the changes are actually taking place?

IV. You are given two bottles, one containing washing soda dissolved in water, the other, alum dissolved in water. Describe:—

(1) the appearance of each solution;

(2) how you could identify the substance in each solution without applying chemical tests.

V. Zinc and magnesium resemble each other in certain respects and differ in others. Mention all the points of resemblance and difference with which you are acquainted.

VI. Write the following names of substances in a column, and, in parallel columns, write opposite to each substance, (1) its constituents; (2) its appearance and any other property it possesses which you have observed:—

bone earth,	antimony,
galena,	sugar of lead,
litharge,	blende,
bleaching powder,	flint,
green vitriol,	gypsum.

DECEMBER 1900.

I. (1) What chemical change takes place when chalk or limestone is "burnt"?

(2) Mention two respects in which the substance left behind differs from the chalk or limestone.

(3) Explain the method of calculating the quantity of this substance which can be obtained from any given quantity of chalk.

II. (1) Make a sketch, occupying one sheet of your answer paper, of the apparatus you have seen used to prepare nitric acid.